



Topic
Better Living

Subtopic
Hobby & Leisure

The Science of Gardening

Course Guidebook

Professor Linda Chalker-Scott
Washington State University



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Linda Chalker-Scott is an Extension Specialist in Urban Horticulture and an Associate Professor of Horticulture at Washington State University (WSU). She received her Ph.D. in Horticulture from Oregon State University, focusing on environmental stress physiology of woody plants. Prior to her position at WSU, Dr. Chalker-Scott taught and did research at Buffalo State and at the University of Washington, where she remains as an affiliate faculty member. In addition to her academic credentials, she is also an International Society of Arboriculture Certified Arborist and a Consulting Arborist with the American Society of Consulting Arborists.

Dr. Chalker-Scott has published a number of literature reviews and analyses in peer-reviewed journals on diverse topics, including the function of foliar anthocyanins, the efficacy of biodynamic preparations, the influence of plant nativity on landscape biodiversity, and a comparative review of landscape mulches. She has also published numerous science-based books for gardeners and landscape professionals. They include the award-winning *The Informed Gardener*; *The Informed Gardener Blooms Again*; *Sustainable Landscapes and Gardens: Good Science—Practical Application*; and *How Plants Work: The Science behind the Amazing Things Plants Do*, which won awards from the American Horticultural Society and the National Association of County Agricultural Agents.

As an Extension Specialist, Dr. Chalker-Scott no longer teaches university courses but instead has an educational outreach program that includes homeowners, Master Gardeners, landscape professionals, restoration ecologists, and landscape architects. Since 2004, she has delivered more than 400 seminars to diverse audiences, reaching more than 25,000 attendees. Dr. Chalker-Scott is also one of the founding Garden Professors, a group of university faculty who provide science-based information for gardeners through their blog and social media. ■

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The Science of Gardening

Course Scope

There are thousands of print and online resources for gardening—but few of them are grounded in appropriate plant and soil sciences. This course focuses on current, relevant scientific information for developing and caring for home gardens and landscapes. The applied sciences that underlie sustainable landscaping and gardening are young and evolving, resulting in new approaches that spark vigorous debate among experts and gardeners alike. You will be introduced to many of these controversial topics throughout the course. Likewise, you will scrutinize many gardening products and practices through the lens of science.

A science-based approach to gardening allows gardeners to become more sustainable in their practices. Though overused and misused, the term “sustainability” has actual value when used in concert with scientific evidence. For the purposes of this course, sustainability embodies the following actions:

- choosing plants and products wisely to conserve natural resources
- creating gardens and landscapes that don't require continuous inputs of packaged fertilizers and pesticides
- discovering and supporting the natural processes that keep home gardens and landscapes healthy, functional, and sources of joy

The first two lessons in this course will demonstrate why a scientific approach to gardening is crucial to long-term success. You will visit some landscapes where trees and shrubs have died long before their time and conduct horticultural crime scene investigations to discover the underlying reasons. These investigations will set the stage for outlining the criteria that will be used to identify reliable sources of gardening information.

The second set of lessons is structured around site analysis and design. Designing gardens and landscapes is an intensely personal process, and science won't be used to dissect it. These lessons will, however, analyze the environmental factors that influence plant choice and placement. Much of the analysis will be targeted to soils, as baseline measurements of soil characteristics are critical to landscape success. Then, you will consider plant selection in the context of morphological features, life history, physiological requirements, and human interactions. The hot-button topic of native plants will be discussed to discover whether science supports the perception of native plant superiority.

The next set of lessons will detail the recommended practices for purchasing healthy plants, preparing and protecting soil, and planting trees, shrubs, and perennials. This segment contains many controversial topics, and you will examine the relevant plant and soil science to discover why new approaches are needed.

The fourth segment focuses on caring for new transplants as well as established gardens and landscapes. Again, you will rely on current plant and soil science as well as soil test results to determine what you should add to your soils and plants and what you should avoid. Many myths will be debunked as not only scientifically unfounded but ultimately harmful to both soil and plant health.

No garden is without its problems, and the fifth set of lessons will focus on diagnosing and solving problems. Once again, you will visit some horticultural crime scenes to practice diagnostic skills. You will discover how to adapt integrated pest management (IPM) for your home garden and landscape. The philosophy of IPM takes a least toxic approach to problems, so you will learn the cultural, mechanical, biological, and chemical methods a gardener might need to consider when battling weeds, insects, and herbivores.

The final two lessons will circle back to the beginning of the course. You will objectively analyze some garden products, practices, and informational sources. Again, the course will address some controversial topics, especially as they relate to correlation of variables and causation of effects. The course will end with a tour of two landscapes to show you how sustainable garden practices can create beautiful, functional, and healthy landscapes.

By the time you finish this course, you will have learned techniques that represent a sustainable approach to caring for gardens and landscapes. The following are a few of the benefits that sustainably managed gardens and landscapes provide:

Ecological/Environmental

- enhanced soil fertility
- enhanced biodiversity of beneficial microbes, insects, birds, and other animals
- reduced contamination of aquatic systems from runoff and erosion
- reduced use of pesticides, fertilizers, and other chemicals

Economic

- reduced labor and material costs for maintenance and plant replacement
- reduced costs for pesticides, fertilizers, and other chemicals
- increased value of property

Human Dimensions

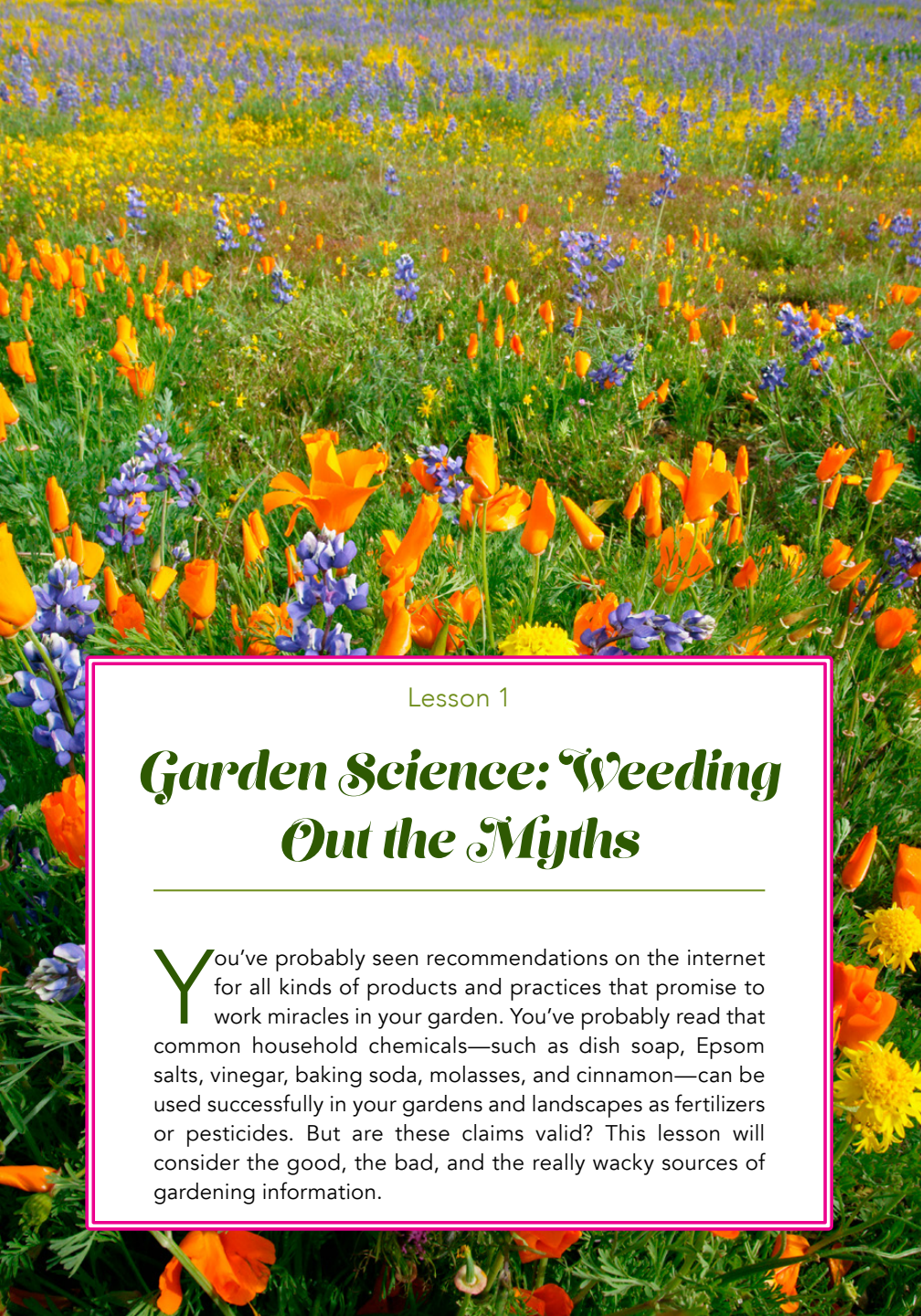
- enhanced aesthetic enjoyment of landscape
- improved physical health and well-being
- increased interaction with neighbors and other people interested in gardens and landscapes

The hope is that this course will not only help you create sustainable landscapes and gardens, but that it will also encourage you to educate others. You can protect and conserve natural resources by practicing sustainable horticulture and teaching others to do the same. ■



This course will introduce you to the most current and relevant research on all aspects of home gardening and landscaping, with an emphasis on permanent landscapes—the trees, shrubs, and woody perennials that make up the backbone and most significant investment of a sustainable garden. The course will review many common problems that home gardeners face, and you'll learn why the latest, well-meaning advice from your neighbor or an online gardening group may not be the best approach. You'll leave this course not only a better curator of your landscape, but also a better curator of sound gardening science.



A vibrant field of orange poppies and purple lupines under a bright sky. The flowers are in full bloom, creating a colorful and lively scene. The orange poppies are scattered throughout the field, while the purple lupines are more densely packed in some areas. The green foliage of the plants is visible between the flowers.

Lesson 1

Garden Science: Weeding Out the Myths

You've probably seen recommendations on the internet for all kinds of products and practices that promise to work miracles in your garden. You've probably read that common household chemicals—such as dish soap, Epsom salts, vinegar, baking soda, molasses, and cinnamon—can be used successfully in your gardens and landscapes as fertilizers or pesticides. But are these claims valid? This lesson will consider the good, the bad, and the really wacky sources of gardening information.

HISTORICAL ROOTS OF GARDENING

- ✿ Historically, agricultural research has looked at food and fiber-related crops. This is where the money is—this is where it's important economically and important for people. Grant money from the U.S. Department of Agriculture and other funding sources is still geared at researching food and fiber-related crops, not ornamental plants. Therefore, products and practices that were relevant to maximizing agriculture production were developed, not products and practices relevant for gardeners.
- ✿ Some of these practices might be similar to what you'd do in a vegetable garden, but many of them are not appropriate for looking at long-term landscapes. Specifically, fertilizers were found that would maximize production, and pesticides were found that would minimize damage from insects and other types of pests.
- ✿ On the other hand, urban landscapes, home gardens, public green spaces (such as parks), and ecological restoration sites are not production agriculture sites, nor are they forestry sites—they are long-term sustainable landscapes that must be managed in a different way. So, one difference is the plant life cycles of these two systems.
- ✿ The second difference is the soil. When you're producing crops, you're plowing, seeding, harvesting, and plowing again, working organic matter back into the soil. And that works well when you're maximizing crop production. But this is something you're probably not going to be doing with your home landscape, because then you would be plowing up all of your perennial plants, whose roots are established in the soil.
- ✿ Then, think about the life that is in the landscape. In a monocultural agriculture system, there's nothing there except the crop that's being managed for. The weeds are taken out. There will be insects and possibly some other animals that live there, but it's a pretty sparse amount of life in terms of diversity. In your landscape, you want diverse life. You want to have different types of plants, insects, and birds because many are beneficial to your landscape. So, there are different management goals for your garden as opposed to just trying to keep a monoculture growing.

- ✿ Finally, and maybe most importantly, think about the use of fertilizers and pesticides. The goal in production agriculture is to maximize production—to get as much out of that field as you can in the shortest amount of time. Part of this involves using lots of fertilizers and reducing pest damage by using pesticides. So, fertilizers and pesticides have always been a historical part of agricultural production, but this is not how we should sustain a long-term landscape system.

RESEARCH AND REGULATION

- ✿ In a research void, there is a plethora of anecdotal, irrelevant, and unverified information. There are a lot of problems associated with following these types of advice, including disappointing results. Also, it's a waste of time, money, and natural resources. And there is a danger to people, pets, and the environment by using unverified chemicals in your landscape.
- ✿ Unlike products and practices that are related to food and drugs, there's no regulatory agency for most of these types of gardening recommendations. You can find all kinds of materials that are sold as biostimulants or tonics or potions, but there's no science or regulation behind them.
- ✿ Because fertilizers and pesticides were formulated primarily for agricultural production, they are regulated. You know exactly how much nutrient content is in a fertilizer; you know what the active ingredients are in pesticides. But there's no agency that investigates the snake oil that is often sold to unsuspecting gardeners.
- ✿ There is great emotional appeal underlying many of these worthless recommendations. First, they sometimes have a folk wisdom feel. You heard it from your grandmother, or from the old guy next door, and it just sounds like great information that's been passed down through generations. Or maybe it just sounds like good common sense. Or maybe it's a do-it-yourself approach. Many people like to be able to make their own products and not have to rely on buying them from the store.

Unfortunately, there are no miracle cures for pests and diseases. There are no magical products that are being suppressed by commercial interests, and there are no forgotten techniques that have been recently rediscovered. But we do have a young and growing body of science-based information that can help us create and maintain sustainable gardens and landscapes.



THE PROBLEM WITH PERMACULTURE

- ✿ A great example of a body of gardening information comes from permaculture, which is a marriage of science and philosophy. While science is testable, philosophy is not. So, we can test the different types of practices that are recommended to see if they actually work, but we can't test and prove a philosophy.
- ✿ This approach falls into the category of pseudoscience, which involves using terminology that sounds like science but is actually not based on scientific processes. You don't really have any experimental evidence to support your recommendations; instead, anecdotal observations are considered to be just as good as science, and better if the science doesn't exist.
- ✿ Some permaculture practices, especially the ones that are based on ecological science, unfortunately are outdated or incorrectly applied. Ecology as a field began its growth in the 1960s, and in many of the permaculture books, recommendations are coming from those old texts—from when ecology was pretty young. It's changed a lot in the decades following, but that information has not translated back down into permaculture.
- ✿ Some of the other permaculture practices, which include lasagna gardening and *Hügelkultur*, are not based on scientific principles. Lasagna gardening is based on mulching to prepare soil for planting and to get rid of weeds and get the nutrients back in the soil—which seems to make sense. Lasagna mulching involves alternating layers of cardboard (the "noodles") and compost (the "sauce"). *Hügelkultur* means "mound gardening" in German and is basically upside-down gardening. You put woody material on the bottom, then more broken-down material, and then soil on top.
- ✿ Unfortunately, the science of these practices doesn't make any sense. These processes don't occur in nature. If you look at mulch layers—for example, in a forest—woody material, such as branches, comes down on top of the soil and breaks down, and the material at the bottom becomes finer and finer until you get down to the soil, which is very fine compost.

- Not only are these processes counterproductive, but sometimes they can cause real damage. For example, in the lasagna garden model, not only do layers of cardboard and then compost not occur in nature, but cardboard is a barrier to water and oxygen movement. Cardboard is made to resist water, and putting layers upon layers over your soil means that water can't get in or out, and neither can oxygen. This mulching method results in your soil being deficient in oxygen.

HOW TO ASSESS GARDENING INFORMATION

- When you hear about products and practices that are promoted by people who are excited about do-it-yourself gardening, folklore gardening, or commonsense gardening, you have to insist on proof—scientific evidence. The onus is on proponents to provide peer-reviewed, published scientific evidence to support their claims. The onus is not on science to prove that it doesn't work.

Evaluating Garden Information: The CRAP Test

To evaluate garden information, use the CRAP test, which stands for credibility, relevance, accuracy, and purpose.

- How **credible** is your resource (who's the author, and who's the publisher)?
- Is it **relevant** to you as a home gardener?
- Is it **accurate**, or is it very dated?
- What's the **purpose**—to give you good information or to sell a product?

- ✿ To assess gardening information, you need to think about the sources that are out there. There is lots of written material. Some of it's good; some of it's not so good. How can you figure out which is which? This falls into three categories: scientific journals, professional journals, and popular books and magazines.
- ✿ There are some great scientific journals that are relevant to gardens and landscapes, including the *Journal of Environmental Horticulture*, *Arboriculture & Urban Forestry*, and *HortTechnology*. These go through a blind peer-review process and are meant for an academic audience, which means they can be dry and dense.
- ✿ Professional journals include *American Nurseryman*, *BioCycle*, and *Arborist News*. These are magazines for professionals that want to know about the newest information. While these publications are edited, they're not peer-reviewed, so the articles may or may not say things that are substantial.
- ✿ Popular books and magazines include *Fine Gardening* and *Mother Earth News*, as well as the plethora of books that are meant for the gardening audience. These popular publications are not peer-reviewed, and the audience is the general public. They are edited and some of them are very readable, but depending on who the author is, it could be excellent information or questionable information.
- ✿ There are also some great online resources. On .edu sites (university websites) and .gov websites (government websites), you might find peer-reviewed, university extension publications that are written specifically for gardeners. On .com websites (commercial websites), a lot of good information can be found, but be aware that they may be selling something rather than just providing good information. There are also open-access scientific journals that you can find online.
- ✿ It's great having information out there for everybody to read, but is it good information? Is it a peer-reviewed journal, or is it a pay-for-play journal, where you can pay to have basically anything you want published? There are different assessment categories.

☼ **Science doesn't support the information.** This category is hugely populated with products and practices. One example is vitamin B₁ transplant fertilizers, which can be found on nursery shelves. It turns out that plants make their own vitamin B₁, so you don't have to add it. It's a waste of money and resources.

☼ **Misapplied science.** A misapplied science has use in one place but is being used someplace else incorrectly. An example is foliar fertilizers, which are great for testing nutrient deficiencies in leaves, but it's not a way to feed plants.

☼ **Overextrapolated information.** This is where you've tested something in a very controlled situation—such as in a laboratory or greenhouse—and it works. But when you take it out into the field, it doesn't work. A good example of this is Harpin protein, which is naturally found in a diseased organism. It turns on defenses in plant cells, but the only way it works is when you can get this protein into the plant cell. You can easily do this in a laboratory in a Petri dish, but you can't do it in the field on plants because they have a protective cuticle, so you can't get that protein inside the leaves.

☼ **Scientific errors.** This is where you might have unqualified researchers, researcher bias, and peer-review failure. Scientific errors are difficult for the nonscientist to ferret out. A great example of this is what you might see on the internet or in pay-for-play journals about how glyphosate is the cause of all human health hazards in the world. In fact, thousands of articles have verified the relative safety of glyphosate to humans.

☼ Why should we care about using scientific, validated practices and products? We'll save money, time, and natural resources by avoiding unnecessary products and practices. We'll reduce the use of pesticides and fertilizers. We'll understand applied plant and soil science and be able to diagnose landscape problems. We'll pay more attention to the natural processes in our personal gardens and landscapes. And we'll be healthier physically, mentally, and spiritually by developing closer connections to our gardens.

READING

Chalker-Scott, *Hügelkultur*.

———, *The Informed Gardener*.

———, *The Informed Gardener Blooms Again*.

Chalker-Scott and Daniels, *Scientific Literacy for the Citizen Scientist*.

QUESTIONS

- ✎ Currently, the only regulated garden products are pesticides and fertilizers, and regulation does not require evidence of efficacy. This regulatory vacuum has created an explosion of untested, unverified products targeted at home gardeners. Should any of these products (other than fertilizers and pesticides) be subject to some sort of regulation? Why or why not?
- ✎ Most people visit medical doctors for questions about their health and veterinarians for questions about their pets' health. Yet these same people willingly follow the advice of popular garden personalities who have no academic credentials. Why?



Lesson 2

Site Analysis: Choosing the Right Spot

One of the strategies for creating sustainable landscapes and gardens is understanding the site conditions before buying plants. In this lesson, you will discover how geographical location affects temperature and water in the landscape. You will also learn what makes specific gardening sites different from what might be predicted by the local climate. In addition, you will discover how parts of landscapes differ depending on their cardinal orientation and how this changes with the seasons. Finally, you will learn how to sample soil, which will help you develop your planting plans and select fertilizers.

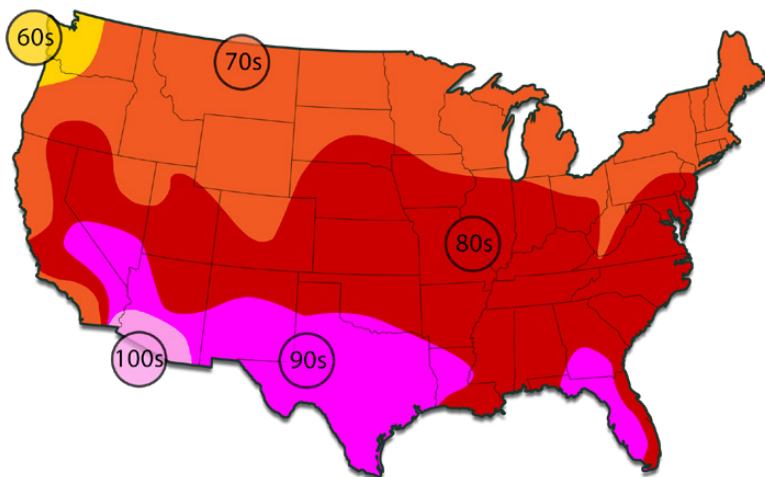


Finding the right plant for the right place is one of the most important decisions we gardeners make. But we tend to make decisions aesthetically, visualizing how lovely a particular plant would look by the front door, rather than considering if the plant will thrive in that location.

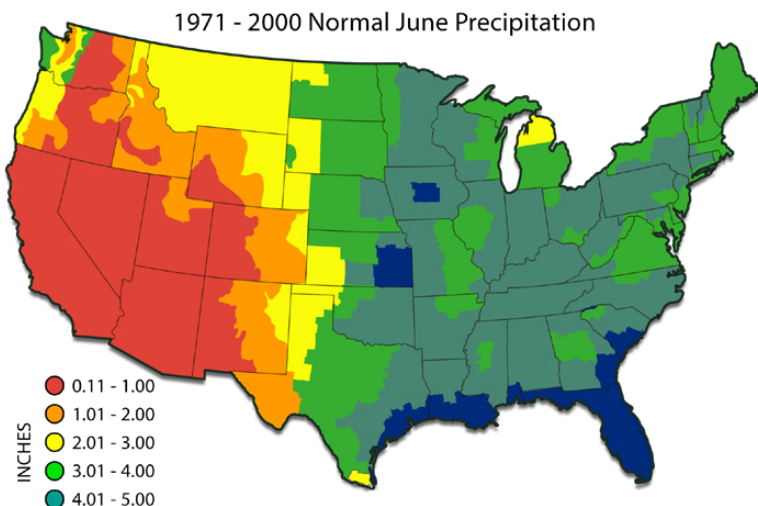
CLIMATES AND MICROCLIMATES

- ❁ Climates are the overriding conditions that affect your geographical region. A climate is a combination of temperature and water.
- ❁ The U.S. Department of Agriculture has maintained a minimum/maximum temperature base for decades because this helps farmers figure out what crops they can grow and where. You can find this information online. You can find out how cold your region gets and how hot it gets, and that will affect the types of plants you buy.
- ❁ Local airports collect average rainfall data that goes into a bigger database that has been maintained for decades. All of the data has been averaged so that you can figure out the yearly average rainfall as well as the seasonality. The average rainfall is important in terms of what types of plants you can grow; seasonality is important in terms of what plants will do well in your climate.
- ❁ Water and temperature determine the plant life that will grow in a region. They also determine soils and organic matter.

Average High Temperatures- June



- ❁ Microclimate combines what happens with the overriding climate and puts in some things that are unique to your particular area. This might include topography. For example, if there is a hill in your location, the top of a hill is very different from the bottom of a hill. Cold air rolls down the hill and sits at the bottom. Topography can change the cold temperature of your area compared to someone who lives just a few miles away.
- ❁ The next thing to consider is slope and drainage of your location. These will influence factors like water movement, so consider them when you're planting. An upslope will be drier; a downslope will be wetter.
- ❁ Next, consider prevailing wind direction. Wind direction is important because it can influence both temperature and water conditions of your plants. Consider cardinal points: north, south, east, and west. How do those conditions change? How do they compare? This will help you decide where to put particular plants.
- ❁ Then, consider shading, such as from trees and structures. Shading will change over time, especially if you've planted trees. Trees are going to get taller, shading is going to change, and your plants are going to perhaps have to change as well.



WATER

- Water is one of the environmental factors that will influence how you select your plants. How available is the water? That doesn't just mean what type of irrigation you have; it also means what the seasonality of your rainfall is. How much rainfall do you actually get?
- You can figure out some issues with soil water by doing a few tests.
 - A percolation test measures drainage, or how quickly water can move through your system. To conduct this test, dig a small hole, fill it with water, and then leave it alone for about 24 hours. This allows the hole to get hydrated. The next day, fill the hole again with water. This time, insert a plastic ruler into the hole and wait for either an hour if you have a fast-draining soil or for 10 hours if you have a slow-draining soil. Cover the hole so that the water doesn't evaporate and come back and measure how far down the water has moved. Once you've determined that number, you can use a reference table to find out if you have an impermeable soil or an excessively drained soil.

Soil Drainage Chart

Drainage Class	Inches/hour	Inches/10 hours
Impermeable	<0.0015	<0.015
Very slow	0.0015 - <0.06	0.015 - <0.6
Slow	0.06 - <0.2	0.6 - <2.0
Moderately slow	0.2 - <0.6	2.0- <6.0
Moderate	0.6 - <2.0	6.0 - <20.0
Moderately rapid	2.0 - <6.0	20.0- <60.0
Rapid	6.0 - <20.0	60.0 - <200.0
Very rapid	20	200

- ⊗ A compaction test also helps you figure out how easily water can move through your soil. When assessing compaction, we look at bulk density, which is measured by grams per cubic centimeter. To conduct this test, dig a small hole, remove the soil, air-dry the soil, and weigh it (in grams). Then, take that same hole, put plastic wrap in it to line it so that water can't move through it. Use a milliliter or liter beaker, depending on the size of your hole, that is filled with water and record the number that corresponds to the starting water level. Fill the hole to the top with water from the beaker and then see how much water is left in the beaker. Subtract that number from the number you started with to determine exactly how much water is in the hole. Milliliters are equivalent to cubic centimeters, so divide the number of grams by the number of cubic centimeters to find the bulk density.

Bulk Density Chart

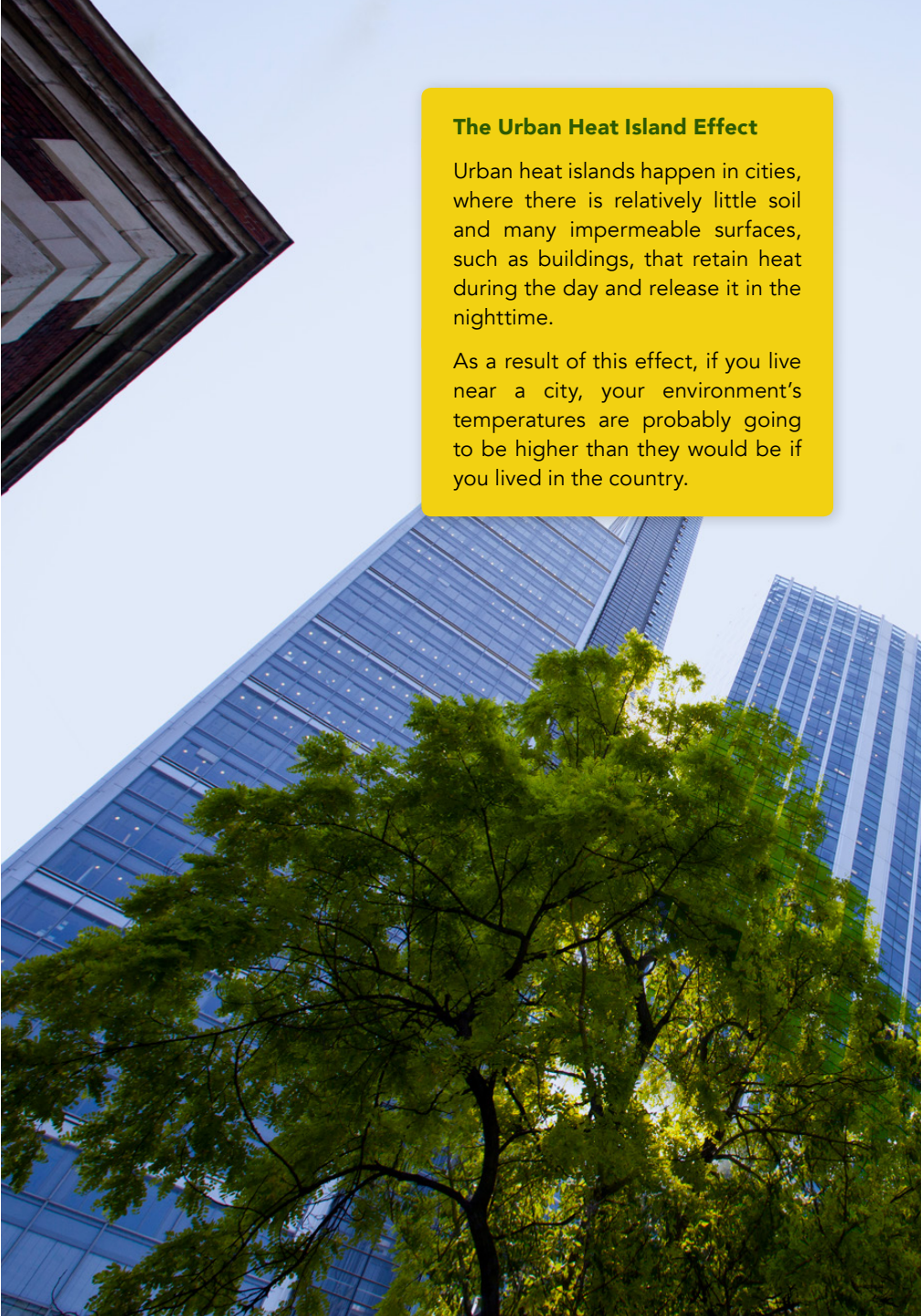
0.2=BD of organic matter
1.0-1.4=BD best suited for plant growth
1.4-1.6=BD that will induce stress on many plants
1.7-2.2=BD of construction site soil
2.56=BD of solid rock

- 🌸 In addition to the water that naturally occurs in your climate, there are some alternative sources of water. One of these is irrigation. Most people irrigate parts of their gardens, but with water becoming more and more of a limited resource, we need to think of some alternatives sources even to irrigation water.
- 🌸 A second source is storm water. During certain times of the year, when you might have intense rainstorms, you can preserve some of this water, not necessarily to use for irrigation later in the year, but to keep it in your soil and in a way that doesn't contribute to runoff. A good example is a rain garden, which is a smaller version of a retention pond. Creating a rain garden helps you manage water, reduces erosion, and perhaps gives you a lovely wetland garden at the same time.

- ✿ A third source is rooftop water. You can have a diversion from your gutter and downspout into rain barrels, and you can keep that water to use for irrigation later in the season. But there are many possible contaminants, such as fecal contamination from rodents or birds, in rooftop water.
- ✿ Another source is gray water, which is water that's been used for another purpose in your household or landscape. Dishwater, for example, is called gray water because it's not potable (you can't drink it), but it's not necessarily toxic to plants. There are also contamination issues here.

TEMPERATURE

- ✿ Consider hardiness. Look at the tags attached to plants in the nursery to see what the zone is for the plant, in terms of how cold it can get and possibly how hot it can get. It might tell you if it's a sun plant or a shade plant.
- ✿ Consider cold pockets. If you're at the bottom of a hill, you're going to have cold air that rushes down the hill.
- ✿ Also consider reflective surfaces—not just white reflection, but dark reflection as well. If you have a light-colored fence or house, sunlight is reflected back at the plants, and even in a shaded environment, you could have enough reflected sunlight that could harm some shade-loving plants that don't tolerate high amounts of sun. Dark surfaces reflect heat back—not just from the sides, but also from the ground up. If you have a lot of asphalt, the heat that comes off the asphalt raises up, and that can actually burn the undersides of leaves.
- ✿ Finally, regardless of what you personally think about climate change, if you're a gardener, you've seen that things have changed in your garden. Perhaps you've been able to grow things that you couldn't grow before because you don't have as cold of temperatures as you used to in the wintertime. Perhaps your rainfall has changed. The climate is changing, and we don't know exactly what's going to do well, so try planting some different things and see how they do.

A low-angle photograph looking up at several tall skyscrapers with glass facades. In the foreground, the dense green leaves of a tree are visible, partially obscuring the lower parts of the buildings. The sky is a clear, pale blue. A yellow text box is overlaid on the right side of the image.

The Urban Heat Island Effect

Urban heat islands happen in cities, where there is relatively little soil and many impermeable surfaces, such as buildings, that retain heat during the day and release it in the nighttime.

As a result of this effect, if you live near a city, your environment's temperatures are probably going to be higher than they would be if you lived in the country.

LIGHT

- ✿ Light is something that you're going to have to consider not just one time before you buy plants, but for an entire year. If you live anywhere other than the equator, your light is going to change seasonally, so every season, you need to go outside and get an idea of where the solar angle is, how it comes into your landscape, and what your plants are going to get in response.
- ✿ You also need to consider the deciduous canopy. Unlike an evergreen canopy, where you're going to have filtered sunlight, the deciduous canopy is going to be sunny in the winter and shaded in the spring and summer. And this will change as whatever you've planted has changed. If you've planted trees, they're going to get bigger, creating a bigger canopy, and you may be disappointed to see that a lot of the plants that you put in as sun plants are now in partial or full shade. You may have to choose new plants as the canopy expands.
- ✿ There are also other types of light to consider. Many people are concerned that moonlight may affect their plants, but this is a myth. Moonlight really has no effect on plants. It does have an effect on insects, which then may affect plants, but it does not have an effect on plants themselves.
- ✿ Photoperiod and dormancy should also be considered. Photoperiod is the ratio of light to dark time. In the summer, you have a very long photoperiod, because the sun is out for a long time, and a short dark period. In the winter, you have a long dark period and a short light period. Plants have an internal biochemical system of analyzing photoperiod that tells them when to go dormant. (Many people incorrectly think that temperature makes plants go dormant.)
- ✿ Finally, consider artificial sources of light. If you live in a city, you're going to have a lot of high-intensity lights, which are so bright that plants can sense the brightness, which messes up their photoperiod measurements. Plants that are really close to these artificial sources of light will not go into dormancy as they should. You don't have to worry about small battery- or solar-powered garden lights; they're not bright enough to affect your plants. But security lights, or other high-intensity lights, can affect your plants.

WIND

- ✿ The more wind you have, the more it's going to cool down the temperature of the environment. In addition to decreasing temperature, wind also decreases the water in the leaves. A lot of wind on a plant can strip the water out of the leaves, causing the plant to desiccate.
- ✿ Cold temperatures plus wind leads to winter desiccation, which leads to plant death. Interestingly, areas on your plants that are covered with snow—which acts as an insulating cover—stay alive while the ones above the snow are stripped of their moisture and die.
- ✿ In coastal environments, wind and salinity come together. If you live in a coastal area, you're going to have some desiccation from the wind, because the salt in the wind can inhibit growth on the windward side of trees.

BIOTIC FACTORS

- ✿ Finally, you need to consider the biotic, or living, factors—and not just how to deal with them, but what you want for your landscape. Do you want your landscape to be children- and pet-friendly? Do you want to attract wildlife?
- ✿ Then, you need to think about the problems. Think about the pests and the diseases. You'll have to do some homework to find out what problems are local for you. Your extension office is a great place to look for new problems that are just emerging in terms of insects and diseases.

TESTING SOIL CONDITIONS

- ✿ Soil testing is one of the most important things you will need to do before you choose the plants that you're going to put into your landscape. First, what do you want to plant there? Is it a vegetable garden? Perennials? Lawn? Trees and shrubs? You need to tell the soil testing lab what you want to have there, not necessarily what is there currently. Second, look at the existing plants, either your landscape or perhaps your neighbors' landscapes—wherever the soil conditions are somewhat similar. What does well? What doesn't do well?

- ✿ Before you do your soil testing, it's very important to take away the mulch first. If you're using an organic mulch, including it in your soil sample can skew your results.
- ✿ Get multiple samples from the same site. Then, combine those samples and take a subsample from that. Finally, keep some of the samples for your own home testing of soil texture analysis, and then send away your lab results.

READING

Chalker-Scott, *Potential Contaminants in Residential Rain Barrel Water*.

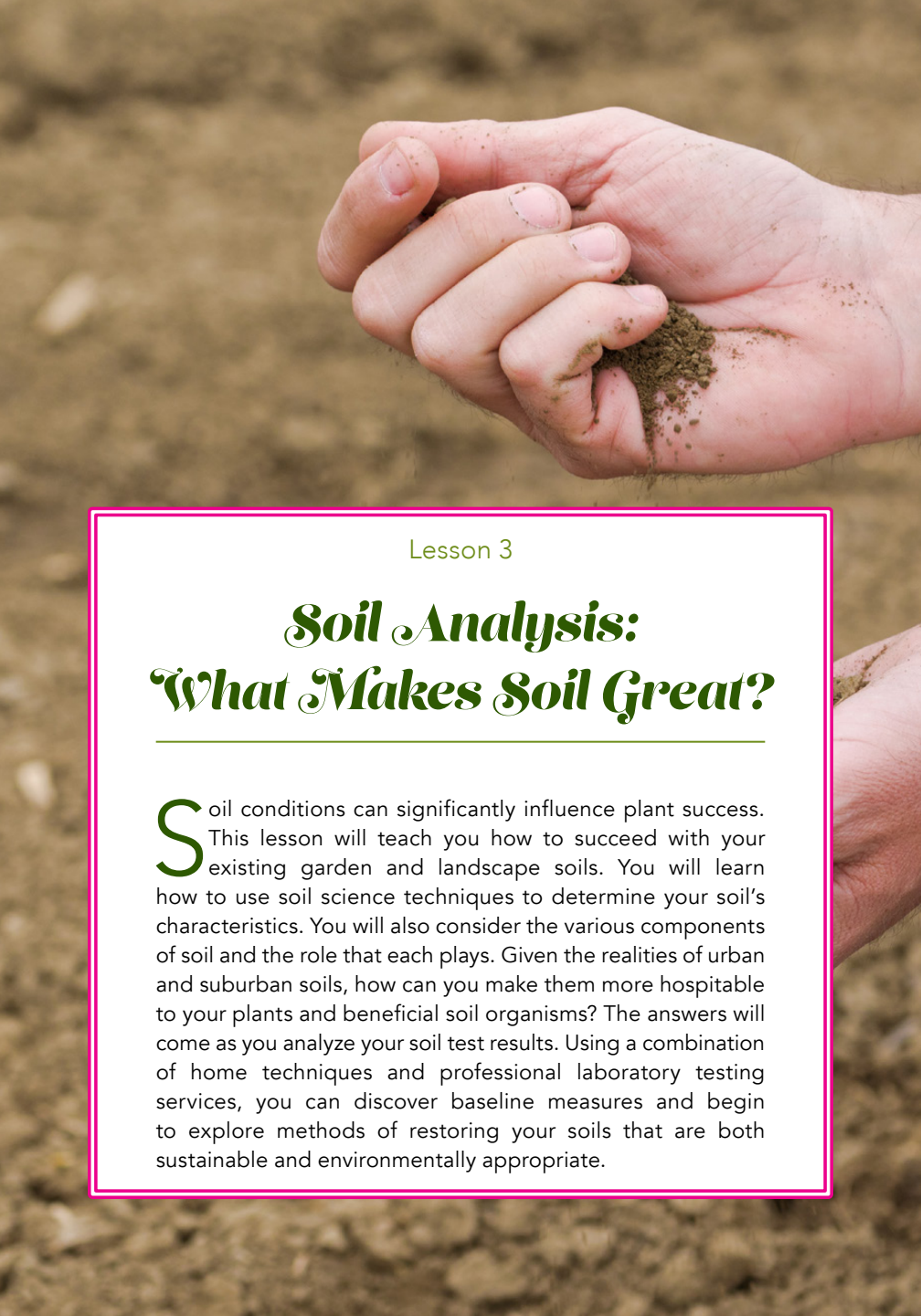
———, *Safe Handling and Use of Rain Barrel Water in Gardens and Landscapes*.

———, ed., *Sustainable Landscapes and Gardens*, ch. 7.

United States Department of Agriculture Agricultural Research Service, "USDA Plant Hardiness Zone Map."

QUESTIONS

- ✎ You decide to try growing a shrub that is marginally hardy in your climate; in other words, it generally needs warmer winter temperatures than is normal for your location. Where would you consider putting it in your home landscape to maximize its chances of survival, and why would you choose that location?
- ✎ Your neighbor claims that you should stop watering your native plant landscape in the fall because excessive water will cause the trees and shrubs to send out new shoots that will die when nighttime temperatures dip below zero. Explain why this is not a concern for your native trees and shrubs.



Lesson 3

Soil Analysis: What Makes Soil Great?

Soil conditions can significantly influence plant success. This lesson will teach you how to succeed with your existing garden and landscape soils. You will learn how to use soil science techniques to determine your soil's characteristics. You will also consider the various components of soil and the role that each plays. Given the realities of urban and suburban soils, how can you make them more hospitable to your plants and beneficial soil organisms? The answers will come as you analyze your soil test results. Using a combination of home techniques and professional laboratory testing services, you can discover baseline measures and begin to explore methods of restoring your soils that are both sustainable and environmentally appropriate.

COMPONENTS AND TYPES OF SOIL

- ❁ Soil is a combination of inorganic and organic components. These components together impart physical, chemical, and nutritional characteristics.
- ❁ The inorganic parts of soil include sand, silt, and clay. These three components have different sizes and dimensionalities. Sand is three-dimensional, round, and gritty. Silt is also three-dimensional and round but is much smaller than sand, and it has a floury texture rather than a gritty texture. Clay is much smaller than silt, and clay particles are flat, not round.
- ❁ Each of these components has an effect on drainage and nutrition. The sandier the soil—the larger the particles—the more drainage you have. This is great for water movement and aeration, but it also means that it's difficult to keep water in place, so these tend to be excessively drained soils.
- ❁ As you work down the sizes, from sand to silt, you have increased water retention and less drainage. By the time you get to clay—with its small, flat particles that tend to form almost impenetrable plates—drainage is at a minimum, and aeration is difficult.

One of the biggest problems for home gardeners is that they are unhappy with their soil. Some gardeners claim to have heavy clay soils, but many of these soils aren't clay. Instead, these soils have been so heavily compacted that they more closely resemble a roadbed than a planting bed.



- ✿ From a nutritional standpoint, the inverse is true: Sand is very bad at retaining nutrients. And the same goes for silt. This is because they can't bind to nutrients. Clay, on the other hand, can bind onto nutrients, hold them in place, and then release certain nutrients and pick up others. For this reason, clay is vital to the nutrition of your soil.
- ✿ The second component of soil to consider is the organic material, which also brings a lot of benefits. Organic material enhances soil moisture. Most organic material is able to absorb and then release moisture slowly. It can also improve drainage and aeration, especially the coarser organic material, as well as provide nutrients.
- ✿ What's an ideal level of organic material for plants? This is an inexact science. We know amounts of nutrients that are important in terms of best growth for certain species, but how does that translate to what's in the soil? To get a very rough estimate of how much organic material is in soil—which is close enough for gardening work—gardeners use percent by volume. Take the results of your soil test, which is given in percent by weight, and double that amount, which will roughly work out to be percent by volume.
- ✿ A combination of two climatic factors will help determine what's a sustainable level for organic matter in your soil. Water will determine whether decomposition occurs: The wetter it is, the more decomposition you will have, which means more organic matter in your soil. The second part is temperature: The warmer the temperature, the more decomposition you will have.
- ✿ Let's consider native and urban or suburban soils. Most people do not have native soils at home unless they live somewhere that's never been touched by human development. Native soils are usually not compacted; they are loose and friable, have good air and water movement, and are naturally aerated by soil organisms, such as worms and moles. These organisms bring air and material up as well as bring material down, and this is how organic matter is worked into the soil naturally.
- ✿ Sustainable levels of organic matter are determined by climate. Native plants come from native landscapes, and urban soils and suburban soils are not native and may not be great for plants that are of native origin.

- ✿ Your home landscape—whether it contains urban or suburban soil—is most likely compacted. If the soil is bare, it will get foot traffic, and poor air and water movement results from that. If you have a lot of vehicular traffic, the vibration from vehicles can cause soils to compact. Water droplets can also cause soils to compact; rainfall or irrigation onto bare soil can cause compaction.
- ✿ A home landscape often has very abrupt layers. Once a house is built and topsoil has been removed, fill is brought in, and that's often called designed soil or landscape fill. It's not true soil. It's a mixture of soil and lots of different kinds of organic matter. This is not necessarily a great thing for native plants, which may have evolved in a completely different type of soil system.
- ✿ Designed soils may not be the best choice for your garden and landscape. They don't usually contain real topsoil—which is hard to find and therefore a very expensive commodity. Designed soils contain various types of material blended into the topsoil, such as sand and organic matter. Sometimes it's far in excess to what's needed by the plants and what's able to be sustained naturally. When you have too much organic matter in the soil, over time, as it decomposes, it's going to settle and subside.
- ✿ Topsoil that is sold in stores is divided into different types of mixes, such as 2-way, 3-way, or 5-way topsoils. The smaller the number, the better. A 2-way topsoil is half loam and half compost. A 3-way topsoil is composed of peat, compost, and 33 percent loam. A 5-way topsoil is composed of compost, garden mulch, peat, sawdust, and 20 percent loam. A 5-way topsoil is the worst of the choices because you get very little soil and lots of organic material.

TESTING YOUR SOIL

- ✿ What type of soil is in your landscape? Is it pure topsoil, or is it a designed soil that may have various levels of shredded leaves, compost, coffee grounds, or peat moss as part of the organic material? There are simple and inexpensive tests that you can do at home and through a soil testing lab to answer these questions.

A close-up photograph of a person's hands, wearing a blue and white plaid shirt, cupped together and holding a large mound of dark, rich, crumbly soil. The soil is piled high in the palms and fingers, with some particles falling back into the larger pile of soil that fills the lower half of the frame. The lighting is warm, highlighting the texture of the soil and the skin of the hands.

Designed soils are aesthetically appealing to gardeners. Many of them are dark, have a fine texture, and look like what a healthy soil looks like. But they don't actually resemble a soil at all.

1. **Settling test:** Put a sample of your soil in a capped jar. Add enough water to the jar so that the soil is in a suspended form but not so much water that you can't shake it well. Shake the jar and then let it sit. After a while, the mixture will separate, with the sand/silt/clay settling to the bottom and the organic matter floating on the top. This will help you determine the relative amount of organic material that is in your soil versus the amounts of sand, silt, and clay.
2. **Ribbon test:** Start with a sample of your soil and add just enough water to get it thoroughly moistened. Then, mix the soil. Put the moistened soil in your hand and squeeze it to make a ball. By working and feeling the ball of soil, you will be able to determine a little bit about what type of soil you have. Your fingers are very sensitive to texture and can tell the difference between gritty sand; smooth, floury silt; and sticky, slick clay. After examining the ball, work it with your fingers and try to flatten it into a ribbon. Use the soil triangle to figure out where your soil fits in terms of texture analysis.

The Finger Test: Estimating Soil Texture in Landscapes and Gardens

While laboratory tests are crucial for determining soil mineral content and other chemical attributes, it is relatively simple to determine soil texture using only water and your fingers. The behavior, appearance, and feel of your sample will help you determine its textural classification as shown in the U.S. Department of Agriculture soil triangle (below). It's helpful to either practice this technique with someone more experienced or compare your finding with a lab analysis of the same soil. In time, you can become quite adept in distinguishing among many of the soil types.

First, hydrate a sample of your soil by mixing a small handful with water until it is fully moistened and pliable. This breaks down aggregates and allows you to see and feel the characteristics that will help you classify your soil. The soil should not be soggy; if it is, add more soil until you have a moistened sample.

Next, squeeze a portion of the moistened soil in your hand, observe the ball that has formed, and compare it to the descriptions below.

Sand: Sandy soils are loose and gritty; because they don't hold moisture well, they are not cohesive. When squeezed in your palm, sandy soils may form a ball but fall apart if touched.

Sandy loam: Like sands, these predominantly sandy soils have a gritty texture, but the presence of silt and/or clay particles make them more cohesive and impart a slightly sticky feel. When squeezed, sandy loams form fragile balls that can be gently handled before crumbling.

Loam: Loams contain relatively equivalent amounts of sand, silt, and clay and are stickier than sandy loams. Moist loams form balls that can be easily handled without crumbling.

Silty loam: Silty loams have a high silt content and little clay. Like loams, they form balls that can be easily handled.

Silt: Silty soils often form clods when dry but are easily crushed into a floury powder. When moistened, silty soils feel silky and form smooth balls that can be handled carefully, but the lack of clay makes them more fragile.

Clay loam: Like silts, clay loams also form clods when dry but are much stickier when wet due to the higher clay content. Interestingly, clay loams represent the most even distribution of clay, sand, and silt in their composition. Moist clay loams form heavy balls that survive rough handling.

Clay: Clays are the most finely textured of the soils and form clods when dry and hard, durable balls when moist.

Often, further information is needed to distinguish among soil textures. This is where the finger test is useful. Take a portion of your moistened soil sample and rub it between your thumb and fingers. Try to form a ribbon with the material and compare your results to the descriptions below.

Sand: Sandy soils do not form ribbons.

Sandy loam: Sandy loams form very weak, gritty ribbons that break easily.

Loam: Loams form soft, slightly gritty ribbons that may reach half an inch before breaking. They do not hold fingerprints.

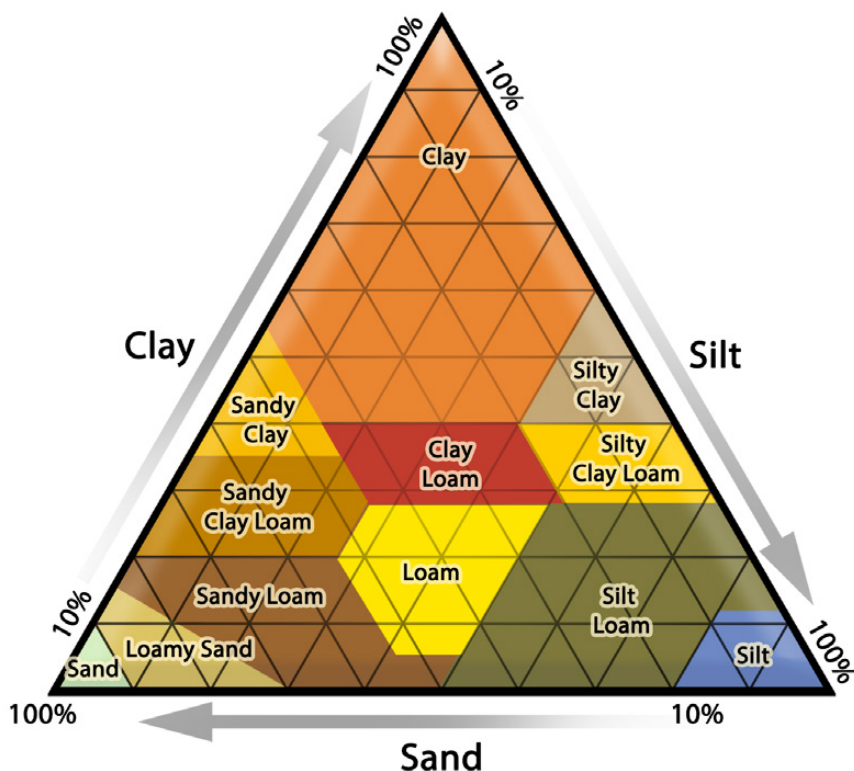
Silty loam: Silty loams form weak, smooth, soapy-feeling ribbons that break easily.

Silt: Silty soils feel soft and smooth when rubbed between the fingers but do not form ribbons.

Clay loam: Clay loams form thin ribbons that may reach two inches before breaking. Although they may show some sheen, clay loam ribbons do not hold distinct fingerprints.

Clay: Clay soils form long, thin, slick-feeling ribbons that are shiny and hold fingerprints.

Soil Texture Chart and Soil Triangle



- Soil pH test:** Kits that allow you to test soil pH are very easy to find and use. The kit requires water, your soil, a reagent, and a color-coded chart. Place some of your soil into a tube and add the reagent and water. Shake the tube vigorously and then let it sit. The grit will move to the bottom of the tube, and the water on the top will change color. Compare the color of the mixture to the chart to determine where on the pH spectrum—from acidic to alkaline—your soil lies.



Soils are made over eons, based on climate conditions—water and temperature—as well as the plants that have grown there for a long time. Because this is what determines soil pH, it's very difficult to change soil pH in any particular area.

4. **Soil testing kits:** You can buy soil kits that are sent to a lab for analysis. Such kits can give you results in terms of specific numbers for your soil's organic matter amount, nutrient levels, cation exchange capacity (how easy it is for nutrients to be taken up by your plants from the soil), and heavy-metal content (which could have an impact on human health). These kits contain very specific instructions on how to take samples. It is important to follow the directions precisely before mailing the kit to the company so that you get accurate information. Do this at least once with your gardens and landscapes so that you know what your baseline measurements are. A report will be emailed or mailed to you, along with information to help you interpret the numbers so that you can adjust the content of your soil as needed.

How Does Soil Science Affect Your Home Gardens and Landscapes?

Unless you live in a completely undeveloped area, native soil is probably not a large part of your landscape, and you are stuck with what you have.

The good news is that gardening science has shown us what the ideal soil looks like: a combination of clay, sand, and silt, with a bit of organic matter. We know that pore space within soil is critical for retaining both water and oxygen and that compaction is primarily to blame for lifeless soil and struggling plants. We have easy tests to determine soil texture and pH, and university and government labs can provide us with additional information about nutrient levels, organic matter content, and possible contamination.

Armed with this knowledge, it's possible to turn nearly any soil into great soil.

READING

Chalker-Scott, *The Informed Gardener*, "The Myth of Phosphate Fertilizer, Part 1."

———, *The Informed Gardener*, "The Myth of Soil Amendments, Part 3."

QUESTIONS

✎ You have removed an old driveway from your landscape and now have a depression to fill. Your choices for fill include the following:

- topsoil blend from a landscaping company
- bags of potting media from the nursery
- a local craigslist ad for free dirt from a landscape being excavated for a patio

Which of these choices is most likely best for backfilling? Why?

✎ Trees grown for balling and burlapping are almost always grown in clay soils. Why is this a practical choice? Why might this pose a problem in your home landscape?



Lesson 4

Living Soils: Bacteria and Fungi

This lesson will continue uncovering what makes a garden soil great by addressing some of the biological components of soil—specifically the microbes. Both beneficial fungi and bacteria grow into and around actively growing plant roots. Roots, bacterial sheaths, and fungal hyphae function to create an intricate underground network. In this introduction to these plant partners, you will learn how some specialized bacteria and fungi are able to penetrate plant defenses and become intrinsic parts of the root system. You will discover specific benefits that each partner receives from these relationships, and you will analyze gardening practices to determine whether they benefit or harm the establishment of these symbiotic associations.

BENEFICIAL MICROBES

- Many microbes are pathogenic, or capable of causing disease, but many other microbes have evolved a symbiotically mutualistic relationship—in other words, both the bacteria (or the fungi) and the plant benefit from the relationship, and there's no detriment to either one.
- In this type of relationship, the plant receives more water and nutrients than it would be able to on its own. This is because the microbes are able to scavenge to find pockets of water and nutrients much better than the plant's roots can. In return, the microbes receive sugars and B vitamins from the plant. Plants manufacture sugars and vitamins; microbes can't make these themselves. These particular groups of microbes are found throughout the plant kingdom.
- Sometimes beneficial bacteria are called plant growth-promoting bacteria (PGPB). These bacteria are divided into several groups:
 - Symbiotic nitrogen-fixing bacteria are often found on legumes, such as peas and beans. This category includes cyanobacteria, which are actually primitive blue-green algae.
 - Free-living nitrogen fixers do not rely on plant roots to survive. Instead, they are found in the soil. But they still fix nitrogen.
 - Free-living soil bacteria don't fix nitrogen.



Many of the bacteria that are beneficial to plants turn out to be pathogenic to humans.

- ✿ How do the nitrogen-fixing bacteria actually get into and “infect” plant roots? (We use the term “infect” because before it became a mutualistic relationship, it was probably a parasitic one.) Plant roots try to keep things like bacteria and microbes out because they could be pathogenic. But in the case of nitrogen-fixing bacteria, the bacteria have evolved a mechanism to get into the plant roots, and then over time have benefited the plant roots, so now the plant roots actually invite them in by releasing a chemical attractant.
- ✿ The spores of symbiotic bacteria are in the soil practically all the time, but they only become active if they are invited to become active. When the roots give off their signal, the spores germinate, creating nodules inside the roots. These nodules are oxygen-free environments where bacteria can fix nitrogen. Within the nodules, the bacteria receive materials from the plant and take in atmospheric (gaseous) nitrogen and fix it into a solid form, which the plant can use for its biochemical processes.
- ✿ What about the other beneficial bacteria, the ones that are not nitrogen fixers but are still able to colonize plant roots? The bacteria are attracted by sugars and organic acids that are secreted by the roots. The bacteria are able to enter the plant roots and suppress the plant immune response by secreting peptides and other chemicals that prevent the plant from getting rid of them. Pathogens do the same thing, but these are beneficial microbes, so the plant doesn’t actively try to destroy them.
- ✿ When these bacteria colonize the plant’s roots, they’re able to prevent colonization by pathogens. Generally, these bacteria make a sheath that surrounds the plant roots, physically removing the space where the pathogens could land. If pathogens try to land and also infect the plant roots, these bacteria have some nasty chemical defenses that attack both bacteria and fungi. For example, some of them can produce cyanide, which kills the pathogenic bacteria; some produce fungal wall-degrading enzymes, which kill the pathogenic fungi.

MYCORRHIZAL NETWORKS

- ✿ Mycorrhiza—or “fungus root”—is a symbiotic relationship between a fungus and a root. It’s almost the rule, rather than the exception, to have some kind of mycorrhizal fungi associated with the roots of plants.
- ✿ One type of mycorrhiza is ectomycorrhiza (“ecto” means “outside”), in which the hyphae of the fungi surround the root tissues—kind of like the sheaths of bacteria, but these are fungal sheaths, and they are actually hyphal tissues. Sometimes they’ll be able to penetrate the root tissues, but not very deeply. They’re mostly an ectomycorrhizal form, which means that they’re just on the outside.
- ✿ So far, there is only a small percentage of plant families that have been found to have ectomycorrhizae, but that doesn’t mean that they don’t exist elsewhere. A small percentage of plants will accept ectomycorrhizal fungi, which form extensive networks throughout the mulch and topsoil layers. They will get into the mulch and create a network that connects the woodchips to the topsoil to the roots. They can hold the woodchips together to retain water and reduce erosion.
- ✿ Another type of mycorrhiza is endomycorrhiza (“endo” means “inside”), in which the hyphae of the fungi are inside the plant roots. These hyphae always enter the root cells and stay right around the roots. They don’t spread widely through the soil and into the woodchip mulches. They are found widely, in hundreds of plant families.
- ✿ How do mycorrhizae infect and colonize plant roots? There are repositories of mycorrhizal spores in coarse organic matter in the soil. They need to have woody material—decomposing wood—especially the ones that are ectomycorrhizal. The spores will germinate under moist and aerated conditions, so the soil has to be relatively moist but not soggy, and it has to be aerated (oxygen has to be present).
- ✿ If the roots are receptive to these particular types of mycorrhizae, they will release a chemical cue to invite the mycorrhizal spores to penetrate them. The hyphae will penetrate the cell walls and create passageways between the plant roots and the mycorrhizae, and then possibly other plants.



When you look at arbuscular ("small tree") mycorrhizae under a microscope, you can see that the fungi penetrates through the plant's cells and then blossoms into what look like tiny trees.

- ❁ Plants are connected to other plants through these fungal channels. The hyphae create sheaths around the roots and extend far into the soil. Often, there will be multiple hosts. If the fungi aren't particular about what plants they can infect, that means that there will possibly be signals going from plants of one species to plants of another. This underground network, and how it might foster plant communication, hasn't been widely explored yet.
- ❁ In these underground networks, the hyphae go through the soil and explore pockets that plant roots can't get into, so they can acquire and transfer nutrients and water to the plant much better than the plant can do itself. These networks also increase soil aggregates, which contain fine roots and clumps of soil and help with drainage and aeration. In addition, the networks improve soil stability, reducing the possibility of erosion. Furthermore, the networks enhance organic matter decomposition. Finally, mycorrhizal networks acidify the root zone by exuding acids into the soil, making it easier for the plant to take up nutrients from the soil.

BENEFITS OF MYCORRHIZAE AND PGPB

- ❁ There is quite a bit of documented evidence for both mycorrhizae and PGPB in terms of what they do for plants. They increase the soil's organic matter. They also solubilize and increase the uptake of phosphate, which many plants can be limited by, especially in alkaline environments. They can take up other nutrients as well and make them available to the plant.
- ❁ Another benefit of mycorrhizae and PGPB is the increase in nitrogen-fixing activity, which is important for leguminous plants; in fact, some of the nitrogen often leeches back into the soil and possibly benefits other plants. Furthermore, these bacteria and fungi will produce stimulatory plant hormones; part of the benefit to the microbe is to stimulate plant growth so that the microbe can feed the plant more, but this is also good for the plant. This leads to increases in leaf, root, and shoot growth compared to plants that don't have these microbes associated with them. Finally, these beneficial bacteria and mycorrhizae can increase both plant survival and establishment.

- ✿ What happens in the soil when mycorrhizae and PGPBs are present? First, soil structure is improved because of the network. Second, the competition for nutrients and water is improved in plants that have these microbes associated with them, compared to plants that aren't mycorrhizal. Third is an increased resistance to many stresses. Having a better water- and nutrient-uptake system means that plants are better able to resist biotic stresses, such as diseases, and environmental stresses, such as drought.

INHIBITING MYCORRHIZAE AND PGPB

- ✿ There are a variety of activities, amendments, and conditions that can inhibit both mycorrhizae and PGPB:
 - ✿ Soil fumigants
 - ✿ Excessive fertilizer application, especially phosphate
 - ✿ Excessive irrigation
 - ✿ Poorly drained soil
 - ✿ Any activity that destroys soil structure, including topsoil removal and compaction



Do not apply fungicides to your soil because they will kill the beneficial mycorrhizae found on the roots of your plants.

ENCOURAGING MYCORRHIZAE AND PGPB

- ✿ There are also many activities, amendments, and conditions that can encourage mycorrhizal activity and plant-promoting bacteria:
 - ✿ Coarse, woody mulch
 - ✿ Conservative additions of nitrogen fertilizer
 - ✿ Warm temperatures
 - ✿ Mild drought or nutrient deficiency
 - ✿ Reduced pesticide use
 - ✿ Reduced soil disruption
 - ✿ Increased diversity of landscape plant materials—for example, living mulch and strongly mycorrhizal plants (woody species)

Packaged Mycorrhizal and Bacterial Products

Packaged mycorrhizal amendments may be effective if you are using sterilized soil, but there is no significant value in adding packaged mycorrhizae to your landscape because your soil already contains native mycorrhizal and bacterial species. Any positive effects that you see are probably due to the added fertilizer in the packaged product. Keep in mind that unhealthy soils won't support the growth of native or applied microbes.

Packaged bacterial products, which are used to stimulate plant growth, might be effective in sterile soil conditions, but beneficial species are probably already in your garden, as long as your soil contains organic matter that is high in nitrogen.

There's no evidence that either mycorrhizal or bacterial products are effective in existing, healthy landscape soils.

READING

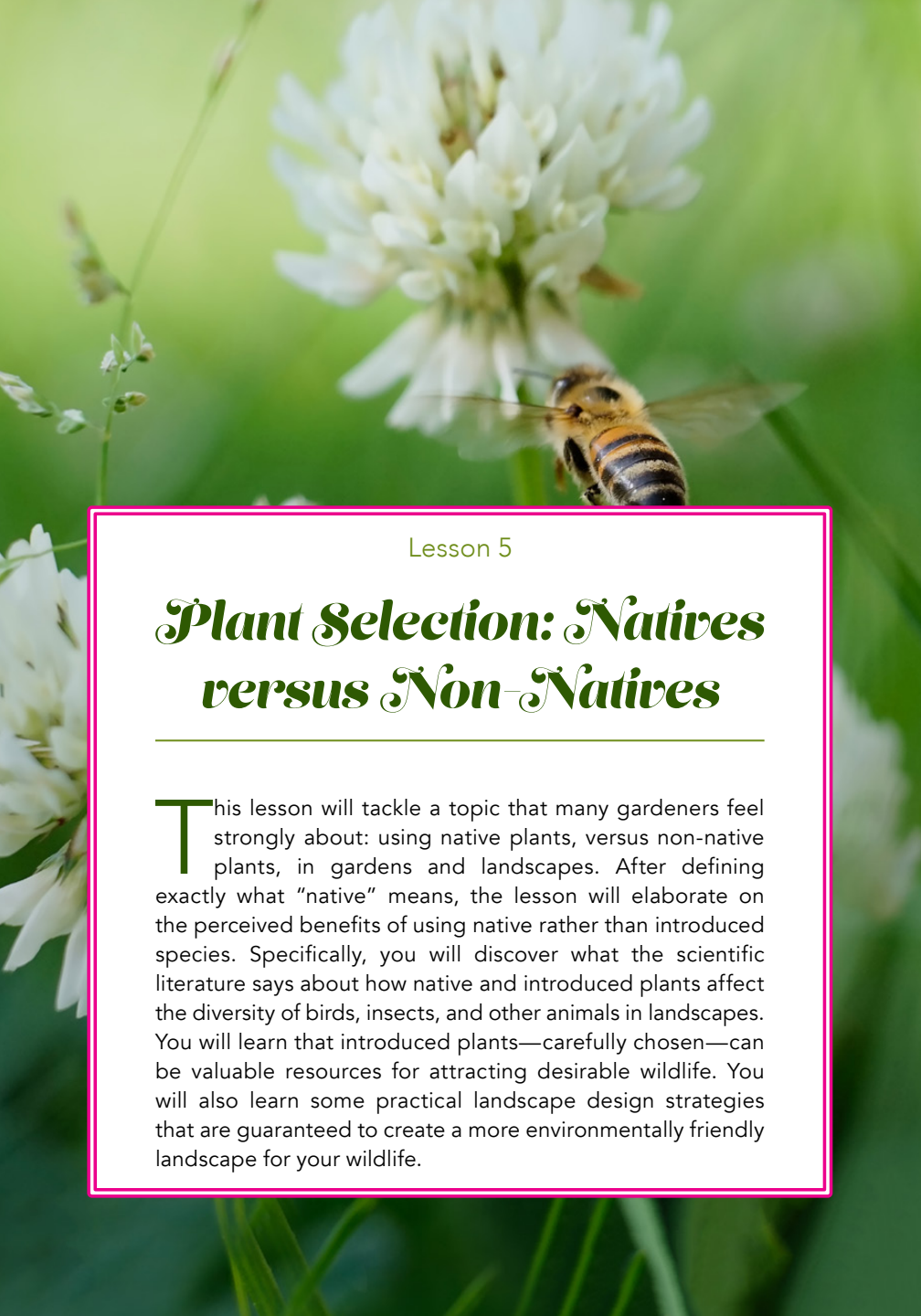
Chalker-Scott, *A Gardener's Primer to Mycorrhizae*.

———, *How Plants Work*, ch. 2.

———, *The Informed Gardener*, "The Myth of Beneficial Bonemeal."

QUESTIONS

- ✎ There are popular "soil conditioner" products that will loosen heavy clay soils. The active ingredient in these conditioners is sodium lauryl sulfate, which is a surfactant. How might this product affect your soil microbes?
- ✎ Spores from plant pathogens such as *Armillaria* and *Phytophthora* are widespread in most soils. Yet landscape trees and shrubs don't usually suffer from these root rots. Why might this be, and how might you use this knowledge to "immunize" your plants?

A close-up photograph of a honeybee in flight, approaching a large, white, spherical clover flower. The background is a soft, out-of-focus green, suggesting a garden setting. The bee's wings are blurred due to motion, and its body shows distinct yellow and black stripes.

Lesson 5

Plant Selection: Natives versus Non-Natives

This lesson will tackle a topic that many gardeners feel strongly about: using native plants, versus non-native plants, in gardens and landscapes. After defining exactly what “native” means, the lesson will elaborate on the perceived benefits of using native rather than introduced species. Specifically, you will discover what the scientific literature says about how native and introduced plants affect the diversity of birds, insects, and other animals in landscapes. You will learn that introduced plants—carefully chosen—can be valuable resources for attracting desirable wildlife. You will also learn some practical landscape design strategies that are guaranteed to create a more environmentally friendly landscape for your wildlife.

ARE NATIVE SPECIES THE BEST CHOICE FOR YOUR GARDENS?

- ✿ Because defining what a native plant actually is can be very subjective, let's consider a native plant to be something that existed in the United States before European settlement. In contrast, a non-native plant would be one that came afterward, whether it came on purpose or accidentally. A subset of non-native plants is the invasive plant, which is one that is so destructive to whatever landscape it's introduced to that it decreases biodiversity and often creates monocultures.
- ✿ People have many perceptions, and misperceptions, about native species.
 - ⊗ First, the rate of extinction of species, whether it's total extinction or local extirpation, is increasing. And a lot of that loss is being blamed on the use of non-native species, especially invasive plants.
 - ⊗ A second misperception is that only native species can fill ecological roles. But species can adapt to other plants that come in to their area as non-native species.
 - ⊗ A third perception is that natives are superior to introductions for many different reasons, including that they are adapted to the local environment, which means that they're not going to have problems with temperature changes, water conditions, pests, and diseases, and that there's a reduced maintenance need for non-natives. They also think that non-native species will not integrate well with existing native species, especially animals.
 - ⊗ A fourth perception people have about native superiority is that native plants give you a sense of place, which plays on our emotions. You see a native plant or landscape that reminds you of home and feel like you are home.
- ✿ All of this concern about using native species has caused many groups to start enforcing planting mandates in certain areas, such as in new developments and along public roadways, and it has affected personal choice of plants.

- ✿ There are rationales behind these mandates. Some go back to the loss of native species that occurs with development. Highway revegetation efforts have often used native plants as a way of bringing some of those natives back. If you're doing ecological restoration, you have to use native plants because you're doing restoration back to the way something was. And there's always the very emotional sense of place.

COMMUNITY DIVERSITY

- ✿ Do native and non-native trees and shrubs (woody plants) differ in how they affect community diversity—the numbers of other plants, reptiles, birds, mammals, and insects that that community can support?
- ✿ A meta-analysis of peer-reviewed scientific articles was conducted to answer this question. The articles that were studied specifically dealt with urban settings, meaning private residences, residential streets, botanical gardens and public parks, remnant natural areas, and golf courses. Ecological restoration sites, which must have native plant palettes, and geographically isolated areas, where bringing in non-native plants can be ecologically devastating, were not considered.
- ✿ In studying how nativity affects landscape wildlife in urban settings, one thing that the scientific articles considered is insect biodiversity.
 - ✿ Many native pollinators have become dependent on introduced plants as their native plants have disappeared.
 - ✿ There are specialist insects that have a very narrow range of affiliated species, so they may be negatively affected by a lack of native species.
 - ✿ The resistance of introduced trees to pests is often the same as or greater than the natives. The damage in natural forests is higher than in urban or ornamental settings. Generalist insects, which have a wide range of affiliated species, can feed on plants in several families, so nativeness doesn't matter.
 - ✿ Community, botanical, and residential gardens support a wide diversity of insects—not just pests, but also pollinators—that isn't found in areas that have only native plants.



Some insects are species-specific and require native plants, but other insects are able to adapt to non-native plants.

- ✿ In addition to insect biodiversity, another thing that the articles considered is how birds fare in terms of native and non-native landscapes in urban settings.
- ✿ Urbanization favors birds that are omnivorous (which eat anything), carnivorous (which eat mostly insects), and granivorous (which eat seeds) as well as cavity-nesting species of birds.
- ✿ Gardens provide fruit and nectar, forest-type trees provide seeds, and urban areas generally have a wide range of resources.
- ✿ The negatives with urban areas tend to be wide expanses of lawns, which are tough on ground nesters and foraging birds who are out in the open and can be attacked by predators, and lack of water, which is a problem if the only source of water is irrigation and ponds or streams are scarce.
- ✿ Native fruit-eating birds can spread invasive species more prolifically than they spread native species.

- How does animal biodiversity fare with introduced species compared to native species in urban settings? This was another question that the scientific literature tackled.
- Introduced tree species, including invasive plants, can meet and diversify habitat needs.
- The richness and diversity of animal species can be enhanced by habitat structure (such as canopy cover, vertical diversity, and tree and shrub density and diversity); larger and/or connected sites; older, larger trees (which provide nesting habitat, protection, and food); hollow trees (which make a great habitat for tree-nesting insects and birds); woody debris (for beneficial insects to colonize); moderately disturbed sites (such as suburbs and public green spaces); profusely flowering species with seasonal diversity; a permanent water source; herbaceous or grass cover (for ground nesters); and native vegetation for specialists.

A close-up photograph showing a person's hands planting a young green shrub into dark brown soil. The person is wearing a green and white checkered shirt. The shrub has many small, bright green leaves. The background is blurred, showing more greenery.

Many gardeners prefer to use natives only because they believe that's better for the native wildlife. But science doesn't support that viewpoint. Instead, science says that the vertical structure, from the ground to the canopy, is what is important for maintaining wildlife.

Native woody species can provide the critical structure necessary for a functional landscape, but there are some other important practical considerations.

- Urban and suburban areas are not natural.
- Native species are often not adapted to the unnatural conditions found in suburban and urban environments.
- Introduced species can provide the ecological benefits that the native species can no longer provide.
- Not all introduced species are invasive.

USING INTRODUCED SPECIES TO ENHANCE GARDEN AND LANDSCAPE BIODIVERSITY

- ✿ There are some selection strategies to consider when comparing urban to native sites. Air pollution is probably going to be more of an issue if you're in a more urban environment. It's probably droughtier in urban and suburban environments than in a native area, but for dry parts of the country, it's probably moister in the urban areas than in a native environment. Heat can be higher and light can be brighter in an urban environment than in a native area. Urban areas can have saltier conditions, and the soils are completely different than the soils that used to be there. Urban areas also have more issues with pests and disease.
- ✿ There are also some selection strategies to consider when diversifying your palette. You need to identify the roles that are needed in the plant community. Think about food value: Do you have the types of plant materials that will provide the nectar, fruit, and leaves for the animals that you want to as part of your landscape? Think about nesting value: Do you have enough diversity in terms of nesting cavities or branches as well as where in the landscape they occur (near the ground or higher up in the canopy)? Think about structural diversity: You should have structures at all levels of your landscape. Think about species diversity: Use natives along with well-behaved non-natives.

- ✿ Finally, there are some management strategies that you can use to help you make a habitat-friendly, wildlife-pleasing type of landscape:
 - ✿ Plant alternative resources before removing invasive species utilized by native birds.
 - ✿ Remove invasive species favored for nesting during the winter.
 - ✿ Maintain a vertically diverse assemblage of trees, shrubs, and ground covers to enhance vegetation structure.
 - ✿ Protect middle-aged trees to ensure that they become old trees.
 - ✿ Plant trees in diverse groups rather than as isolates or monocultures.
 - ✿ Enhance vegetation at landscape edges—called buffer strips—and leave them alone.

A photograph of a woman and a young child in a garden. The woman, wearing a straw hat and a plaid shirt, is kneeling and holding a silver watering can. The child, wearing a white shirt and blue shorts, is standing next to her, also holding the watering can. They are surrounded by lush green plants and purple flowers. The scene is bright and sunny.

A rich mixture of plant species in your gardens and landscapes can become a haven for desirable wildlife, as well as for you and your family.

- ✿ Maintain deadwood and other nesting structures in place when possible.
- ✿ Reduce managed, open lawns when possible.
- ✿ Protect quality of surface waters.
- ✿ Reduce soil compaction with organic mulch.
- ✿ Adopt less intrusive practices.

READING

Chalker-Scott, "Nonnative, Noninvasive Woody Species Can Enhance Urban Landscape Biodiversity."

———, ed., *Sustainable Landscapes and Gardens*, ch. 8.

———, *The Informed Gardener*, "The Myth of Native Plant Superiority."

———, *The Informed Gardener*, "The Myth of Well-behaved Ornamentals."

QUESTIONS

- ✎ There are arguments among native plant enthusiasts as to whether nativars, or cultivars of a native plant species, are just as good as native species for use in the home landscape. What would be the benefit(s) of using nativars? Are there any drawbacks for home landscape use?
- ✎ An article in your local newspaper states that using non-native plants in home gardens and landscapes will doom native insects and birds who depend on native plants. Write a letter to the editor, targeted for the home gardener, that explains why this isn't true from an ecological and/or evolutionary perspective. Try to include local examples of non-native plants that support native wildlife.



Lesson 6

Plant Selection: Function and Form

This lesson will introduce you to the many roles your plants can play in your landscape, with a focus on the backbone of your landscape: trees and shrubs, as well as ground cover plants. As a sustainable gardener, you will want to assign jobs—such as moderating the microclimate around your house—to your permanent landscape plants. This lesson will also address some of the morphological and physiological considerations in your plant palette. Finally, you will learn about a science-based approach to creating your home landscape.

THE ROLE OF YOUR PLANTS IN YOUR LANDSCAPE

- ✿ What do you want your plants to do? What is their role in your landscape?
- ✿ If you live in a city or somewhere that has fairly small lot sizes, one of the most important things your plants can do for you is serve as a screen. Screening hedging can help keep your privacy at a maximum and noise at a minimum. For both privacy and noise control, choose evergreen plants. Avoid, if possible, not having all of one species; intersperse different types of evergreens with each other.
- ✿ If you're looking for summer shade but still want winter light, choose deciduous plants. If you decide to use deciduous plants, make sure to select ones that will tolerate being pruned—ones that have small leaves that tolerate shearing and look great after being pruned.
- ✿ When you're first choosing your plants, keep in mind that trees and shrubs will grow and fill in space, so don't overplant them. Figure out the final size of your plants before you plant them. Make sure that you have sufficient space between the trees and then fill in the gaps with other materials, such as fencing, a trellis, or climbing vines. As the trees grow, you can remove those added materials and let the trees fill in the space.
- ✿ Another role your plants can serve is the modification of your environment. You can use plants to moderate both temperature and light in your environment by using plants that will provide various levels of shade depending on what you want.
- ✿ You can also moderate storm water. If you're in an area that gets heavy torrential rains and don't want your soil washing away, use plants that are adapted to being in very wet conditions that will suck up the water and store it.
- ✿ Additionally, you can channel wind. If you're in an area that gets a directional wind that is unpleasant, you can put trees and shrubs in such a way that channels the wind around or over your house.

- ✿ Not only can your plants help modify your environment, but they can also help modify behavior, both of people and of animals. You can use plants to create or restrict social paths; instead of having your lawn trampled when people cut across your lawn, you can use plants—as well as hardscape structures, such as fountains or benches—to guide people along a path where you would prefer them to go.
- ✿ You can also help restrict animal movement. You can keep pets or other wildlife out of a particular area by using plants that are too thick to climb through or that smell bad to the animal.
- ✿ Another important use for plants is managing crime. Put low plants in front of your windows; having large trees or shrubs in front of your windows gives criminals easy access to your house because the trees block your sight and conceal them. You can also use plants that are particularly dense or that have thorns or other types of unpleasant foliar characteristics to keep people from entering areas you don't want them to enter.
- ✿ In addition to environmental and behavioral modification, you can consider wildlife habitat—assuming that you want wildlife, which might include some pests as well as desirable animals. You can choose plants that will provide food, nesting, and protection for wildlife.
- ✿ Erosion control is a very important part of keeping a healthy soil. It's making sure that the soil stays on site. Woody plants, with their roots and mycorrhizal associations, along with the fibrous roots of grasses, will help anchor the soil and keep it from blowing or washing away.
- ✿ Think about living mulches when you're trying to maintain soil. A mulch is anything that covers a soil and reduces erosion, runoff, and compaction. You can include turf and other grasses as part of a diverse living mulch.

Use the information in this lesson to view your home landscape through a new lens. Do you have a problem situation that could be addressed through informed plant selection? You can use plants to direct foot traffic, to screen you from neighbors and noise, or even to keep you cool in the summer. Most importantly, your plants function to protect both soil and water health, all while creating personal space that reflects your aesthetic preferences.



PLANT MORPHOLOGY AND PHYSIOLOGY

- ✿ Let's consider what our plants look like, which is their morphology, as well as how they function in a landscape, which is their physiology.
- ✿ Morphology refers to the overall appearance of plants.
 - ✿ When you're choosing your plants, think about the mature size. Consider genetics: Some plants will be tall naturally while others won't be, and particular sizes will work for your landscape.
 - ✿ Also consider how the environment will change, especially with regard to the climatic factors of water and temperature. The more water there is and the warmer the climate is, the taller plants can grow.
 - ✿ Think about competition. If you're going to be planting a very dense garden, there will be a lot of competition between species of plants, and that may change your landscape over time.
 - ✿ Keep mature size in mind when choosing plants for small sites and shallow or restricted soils that are common in urban areas.
 - ✿ Also consider both hazard and nuisance issues. Avoid plants with toxic fruits in the parts of your landscape where children or pets may eat them. Also avoid plants that shed their fruits around sidewalks and other areas where you walk or drive so that you don't end up with a sticky mess. Avoid plants that give off a bad smell, such as female ginkgo trees, whose cones smell terrible when they're squished.
 - ✿ Thorns are a positive if you want to keep people and animals out of a certain area, but thorns might not be so great for children and pets. And if you're a gardener, especially a bare-handed one, thorns are a nuisance.
 - ✿ Most people love pollinators, such as butterflies, bees, and birds. But if you or someone you know has a bee allergy, you may not want to have a lot of plants in your landscape that attract bees. Also consider that butterflies and moths come from caterpillars, which eat plants.

A large, mature tree with a thick trunk and a wide canopy of bright yellow leaves stands as the central focus. The tree's branches are dark and intricate, with the yellow leaves providing a stark contrast. The ground is covered in a thick layer of fallen yellow leaves, with patches of green grass visible. In the background, other trees with bare branches and some with light green foliage are scattered across a grassy park area. A low stone wall and a park bench are visible in the mid-ground. A small, dark lamppost stands to the right of the main tree. The sky is a pale, overcast blue with soft, wispy clouds. A yellow text box is positioned in the upper right corner of the image.

Even if genetics says that a plant will grow to a particular height, how high it will actually get depends on where you live.

- ✿ Physiology refers to how the inner workings of plants are affected by the environment. Physiology can influence how you select your plants and can also affect morphology.
- ✿ Consider the most important abiotic factors: water, temperature, and light. But in certain environments, you may need to also consider salts, winds, and other types of local conditions that may make certain plants unacceptable and other plants better equipped for your landscape.
- ✿ At a plant nursery, tags mark plants as sun plants, shade plants, or both and tell you how much plants will tolerate these conditions. Plants that can tolerate both sun and shade can show distinct morphological changes, such as color changes in leaves, as conditions change during the year. But even though plants may be tagged as preferring certain light conditions, they are genetically equipped to change their morphology to tolerate less-than-desirable conditions.
- ✿ In addition to being grouped by light levels, plants are often grouped in nurseries according to their water desires, or they are tagged as preferring wet soils or dry soils. If not, there are other ways to find out what will tolerate dry or soggy conditions in your area.
- ✿ This is where leaf morphology comes in handy. Plants with big, flat leaves tend to not do well in dry conditions because there is a lot of space for water to evaporate from. Plants can have wavy layers or soft, silky hairs that are made to help the plant retain water and therefore tolerate dry conditions. Shade plants typically have very thin leaves that are adapted for picking up a lot of light.
- ✿ You might have a section of your landscape that's poorly drained or wet. While these can be challenging spots in a landscape, some beautiful and useful shrubs and trees thrive in these conditions, such as mallow, joe-pye weed, and buttonbush.
- ✿ In addition to abiotic factors, you should also consider biotic factors—the living parts of your landscape, whether they are desirable or undesirable. Think about plants that will be resistant to

pests and disease. Keep in mind that most of our problem garden pests and diseases are introduced. It can be difficult to select resistant species.

- ⊗ Also consider interactions with other plants. Competition for water, sun, nutrients, or space will occur, especially as your landscape grows and starts to fit together.
- ⊗ Using synergism, plants can be used to prepare pockets in your garden that are more conducive to other species; for example, if you want to provide shade for shade-loving plants, start out with plants that will tolerate the sun, and as they grow, they will shade the area. This is ecological succession. This is not companion planting, which in the popular sense is more like a plant dating service.



Many gardeners complain that they have poorly drained soils and don't know what to do. They usually want to change their drainage, which is usually not possible. The best thing to do is select plants that will tolerate, if not love, that poorly drained soil.

A SCIENCE-BASED APPROACH TO CREATING HOME LANDSCAPES

- ✿ When creating your home landscape, diversify your plant palettes. Don't worry about everything being a native plant; use some non-natives that will do well in your landscape.
- ✿ Consider food value, not just for the birds, butterflies, and other charismatic macrofauna, but for insects living in the mulch and microbes living in the soil.
- ✿ Also consider nesting value. Birds are an obvious target for this, but also make space for insects who build nests in the landscape—perhaps underground or in the bare soil under your shrubs. Maybe they'll stay out of your house if you provide them with an outdoor habitat.
- ✿ Structural diversity—horizontal as well as vertical—is also important.
- ✿ Consider species diversity. Choose plants that are not members of the same families. Increased genetic diversity ensures increased resistance to pests and disease in your landscape.
- ✿ There are also some management strategies to consider. When dealing with invasive plants, keep the soil covered so that there are no bare spots. Create conditions that suppress invasive plants; shade them out and reduce their water availability.
- ✿ You can enhance your landscape diversity, both horizontally and vertically. Reduce monocultures of lawn—which, while aesthetically pleasing, are difficult to manage and are prone to pests and disease. Consider ecoturf and other types of ground covers that will grow best in your landscape.
- ✿ Visit some parks, arboretums, and other places where the lawn isn't heavily managed to see what grows there naturally. Maybe you can use some of the same plants in your landscape.
- ✿ Along with horizontal diversity, also consider vertical diversity, which is created by changes in plant materials and ground covers to herbaceous perennials, then shrubs, and finally trees. Not only is this aesthetically pleasing, it's great for creating habitat for wildlife.

READING

Chalker-Scott, "Nonnative, Noninvasive Woody Species Can Enhance Urban Landscape Biodiversity."

———, ed., *Sustainable Landscapes and Gardens*, ch. 8.

———, *The Informed Gardener Blooms Again*, "The Myth of Uniform Plant Performance."

QUESTIONS

✎ Every state has a list of its champion trees—the largest specimens of those trees for which a list is kept. For example, the following are some champion specimens of *Ginkgo biloba*:

- 90 feet: Tennessee state champion
- 80 feet: Alabama and Ohio state champions
- 72 feet: Texas state champion
- 57 feet: Arkansas state champion
- 24 feet: North Dakota state champion

What might be some of the reasons for the differences among state champion trees?

✎ You might have been told never to plant anything under black walnut trees because they produce a toxic chemical (juglone) that will kill other plants. While this allelopathic chemical is known to exist and have effects in the laboratory or greenhouse, it has not been found to be a cause for mortality in the field. In fact, many people successfully grow a variety of plants beneath walnuts. What might be some other reasons for plant mortality mistakenly attributed to juglone toxicity?



Lesson 7

Plant Selection: Finding Quality Specimens

This lesson will teach you how to use practical plant physiology to choose or avoid plants at the nursery, focusing on trees and shrubs, not only because they are the backbones of permanent landscapes, but also because they can cost a lot of money. You will learn how to look for key indicators of hidden flaws. You will learn about taper, root flares, suckers, and grafts. You will discover how to inspect trunks and branches for signs of improper pruning. As you will learn, half the battle to successful tree and shrub planting is starting out with healthy plants.

ASSESSING QUALITY IN PLANT NURSERIES

- ✿ The following are types of plant materials that you might be able to find in a plant nursery:
 - ✿ Bare-root stock: Only available during a small part of the year, usually in the late winter or early spring, when they're dormant. These are generally the best quality plants, but they are relatively small.
 - ✿ Containers: Generally filled with soilless media, which encourages root growth and is light and easy to manage.
 - ✿ Balled and burlapped (B&B): A ball filled with clay and covered with burlap. These are often the largest trees available, but they may come with serious root problems.
- ✿ You want to assess the general health of the plants at the nursery. Look for evidence of weeds, pests, diseases, and nutritional issues. You don't want neglected plants. After doing an overall assessment, you want to start looking at specific plants. Start by looking at shoots.
 - ✿ Look for evidence of inappropriate pruning. Single-trunked trees should stay single-trunk trees. As these trees grow, if they've been pruned, you'll get competing leaders, sometimes called codominants, which leads to health problems. Side branches are important to young trees. They shade the bark to keep it from getting sunburnt and provide food to the trunk. If you remove the side branches, the trunk will be scorched from exposure to the sun and the trunk won't be healthy.

We often buy the biggest trees possible, even though they can cost hundreds of dollars, and we're drawn to trees that are pruned to look like miniature adults rather than left in their straggly but natural teenaged form.

In many cases, we have just become impatient with waiting, and we want the perfect landscape now. We've started to regard trees and shrubs as design elements rather than the living, changing organisms they are.

Inappropriate pruning is a common problem. Sometimes trees are cut down or topped to make them smaller. This pruning will increase further growth, turning the tree into a multiheaded hydra that you have to continually maintain. Some trees naturally have a multitrunked appearance, and it's okay if those trees have been pruned.



- ✿ Look for taper, which is a flared structure that develops naturally in trees as they're exposed to wind and other kinds of movement and that helps hold the tree in place. From wherever the trunk starts to the soil, the trunk should flare out. If you don't see this flared structure, there could be a problem underground.
 - ✿ Look for grafts. Many trees have been grafted onto vigorous root stock, which is great, because it means that you can grow some rather unusual trees on root stock that will survive your landscape's conditions. On the other hand, the root stock can be so vigorous that it might overtake the graft and lead to problems.
 - ✿ Look for signs of damage or disease. Most of the time, these are culled out before they get to the retail nursery, but sometimes things slip through the cracks.
- ✿ Then, you want to assess root quality as much as you can without uprooting the tree or shrub. You can do that when you get home, but you can't do it at the nursery.
- ✿ Determine whether the size of the container is big enough for the plant. Because this height-to-size ratio is difficult to quantify, use the tippy test: If the tree looks like it's going to tip over, that probably means that the top is too big for the size of the container, and you can bet that the roots are going to be very constricted in the container. When a young tree or shrub is growing a lot above ground, it's also growing a lot below ground.
 - ✿ Look for surface roots, which are roots that have started growing over the top of the soil. Surface roots signal that there are root problems underground. Maybe it's been in the pot too long and the roots have nowhere else to grow but up, or maybe it hasn't been potted properly.
 - ✿ Look for root flare, which is the place where the roots meet the trunk. Taper goes from a narrower point to a wider point, and the wider point is the root flare. Trees in nature always have root flares. The existence of a root flare means that the plant is planted at grade, which means that it's planted at the proper level—not too high or too low. If it's planted too high, the roots can dry out; if it's planted too low, the roots can suffocate and get diseases that occur underneath the soil along where the trunk has been buried.

- ☼ Look for suckers, which are stems that pop up from the roots and compete with the tree. Suckers are not a problem for multitrunk species, but if a single-trunk species has suckers, there is probably a problem underground with the roots. The plant is essentially dwarfing itself, or making itself a smaller tree that can get water easier because of the root problems that aren't allowing water to get up to the top of the existing crown.
- ☼ Look for damage or disease. A few leaves that have been diseased, maybe at the end of the season, are not a problem, but if the tree has damage to the trunk, bark, or any other permanent structure, avoid it. Trees like this are normally culled out by the nursery before they go into retail, but sometimes things slip through.

Nursery Checklist

Choose plants that

- ☑ have heights that are appropriate to pot size;
- ☑ have good taper;
- ☑ have a visible root flare (are not buried too deeply);
- ☑ do not have surface roots;
- ☑ do not have suckers;
- ☑ are free from damage and disease;
- ☑ have not been improperly pruned;
- ☑ have a strong central leader (unless multiple leaders are natural for the species);
- ☑ have branches that are well distributed along the trunk; and
- ☑ do not have included bark.

RESCUING LOW-QUALITY PLANTS

- ❁ If you see a low-quality plant that you really want, even though you know that there are problems with it, there are a number of things that you can do.
 - ❁ When you get home, you might be disappointed in how a plant looks after it has been in your garden or landscape—or even just still in the pot—for a few days. It may not look as great as it did in the nursery—but that’s perfectly natural. The reason for this is because plants in nurseries are getting constantly managed in terms getting lots of water and fertilizer, and they’re probably not going to get this kind of attention at your house.
 - ❁ If you want a comparison on what the plant might look like in your landscape, go to a big-box store, where they maybe aren’t as careful with watering and fertilizing. They probably won’t look quite as good as the plants that you’ll find in the nurseries.



If you want to practice the techniques you’re learning about in this course, go to the sale section of a nursery and buy something that is inexpensive that you can practice on.

- ✿ Give it some time. Let the plant recover. If it's a bad time to plant, just leave it in the pot for a while. Think about where you're going to put your plant before you plant it; it's much easier to move plants in containers to various parts of your landscape rather than trying to do this after you've planted them.
- ✿ When you get home, prune any dead, damaged, or diseased materials that you find on the plant.
- ✿ When you are ready to plant, remove all foreign materials, including pots, burlap, twine, wire baskets, and all soil or potting media. This eliminates all barriers between the roots and the native soil so that the roots can get established and grow properly. This also allows you to see the roots and correct any issues you might notice. In addition, this allows you to find the root crown so that it can be planted at grade. It is also good for herbaceous perennials to remove soilless media.
- ✿ If you get to the point that you've removed all foreign materials and notice that the roots of your plant are dead, dying, or diseased—things you couldn't see until you took everything apart—you can take the plant back to the nursery. But there are some restrictions. There are often limits on how long after you've bought the plant that you can return it, and there are warranties that say if you disturb the root ball, you won't get your money back, so you might have to take a risk.
- ✿ It's important to show any quality-related problems to the nurseries, because these types of problems are often not caused by the retail nursery, but during the production process. Nowadays, production nurseries have mostly automated systems where workers are still doing the potting, but they're often low paid and don't necessarily have the education or background required to know how to move plants to and from different-sized pots. The emphasis is often on speed, not plant health.
- ✿ The root system of a plant is fragile and something that needs to be taken care of, and this is often ignored at the production level, so you end up having problems that you don't see until you get your plant home and unpotted.



When you bring a plant home from a nursery, you may have heard that you're not supposed to disturb the root ball because the root ball will collapse and the tree will die. But this is actually bad advice. From a scientific viewpoint, it's much better to get rid of all barriers—such as burlap and twine—between the roots and the native soil.

- ✿ If you have a warranty that won't allow you to get your money back, take pictures of what the plant looks like before you take it apart as well as how it looked after you took it apart. Take the plant back to the nursery so that they can send a message to the production nursery that plant quality is suffering due to production methods. When it comes to quality, change has to be made at the production level.

READING

Chalker-Scott, ed., *Sustainable Landscapes and Gardens*, ch. 11.

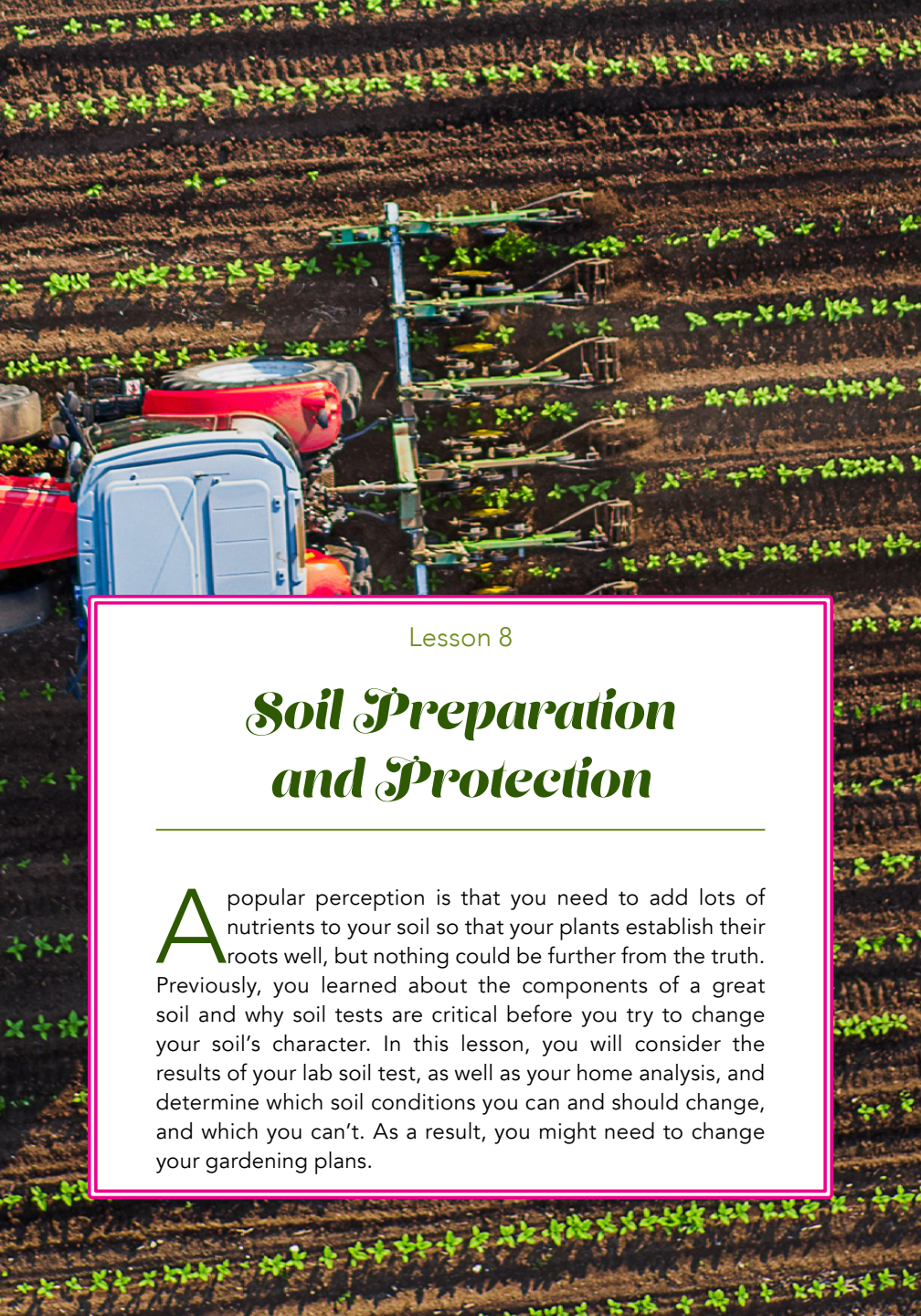
———, *The Informed Gardener*, "The Myth of Plant Quality."

———, *The Informed Gardener Blooms Again*, "The Myth of Xeriscaping."

QUESTIONS

- ✎ An old gardening myth is that trees and shrubs should be planted into the landscape facing the same direction they were grown in the nursery. Why might this advice have been perpetuated? Is it likely to be of practical use?
- ✎ Visit your local nursery and find examples of these tree quality problems:
- no visible root flare
 - surface roots
 - topping

Inspect these trees as well as you can without disrupting the container or burlap. Would any of these plants be worth buying? What would you need to do to improve their chances of survival?



Lesson 8

Soil Preparation and Protection

A popular perception is that you need to add lots of nutrients to your soil so that your plants establish their roots well, but nothing could be further from the truth. Previously, you learned about the components of a great soil and why soil tests are critical before you try to change your soil's character. In this lesson, you will consider the results of your lab soil test, as well as your home analysis, and determine which soil conditions you can and should change, and which you can't. As a result, you might need to change your gardening plans.

SOIL TEST RESULTS

- ✿ Before you adjust your soil in any way, look at the results from your soil test. Among other things, you can find out what the pH is. Find out what's typical for your part of the country in terms of the alkaline-acidic scale. The pH of your soil will be a factor when you choose your plants.
- ✿ Then, consider organic matter, which is reported as percent by weight, not volume. Unfortunately, this measurement is not a very practical one because you can't add stuff back to the soil by weight—you add it by volume. Translating weight into volume is very difficult, so figuring out how to match what the soil test tells you that you should have versus what you actually have is a problem. To make matters worse, the natural levels for local climate, which you can find on soil tables in your region, is also always reported as percent by weight.
- ✿ Your soil test will give you a report on the nutrient levels of your soil, including deficiencies and toxicities, and this will be addressed in an upcoming lesson. You might test your soil for heavy metals, especially if you have a vegetable garden, and this issue will also be addressed in an upcoming lesson.

ADJUSTING YOUR SOIL

- ✿ Next, consider how to adjust your soil conditions. What can you change, and what can you not change?
- ✿ There are some things that can be changed relatively easily, although they may not be permanent. Organic material can be added easily. But the problem is figuring out how much to add and then how to add it.
- ✿ Consider the different types of organic material you may have. When you compare various organic materials, weight varies drastically, even if the volume is the same. In the landscape, it's impossible to add organic materials by weight; the only practical way is to add by volume. For example, you could incorporate one inch of compost into the top three inches of soil, which would give you 25 percent of organic matter.

- ✿ Because it is so difficult to convert from volume to weight, and vice versa, it's much easier to add the material on top and let it be incorporated naturally. This method is also better for soil structure.
- ✿ Nutrient deficiency is also relatively easy to change. If you need more of a particular nutrient, you can find a fertilizer that has that nutrient, either alone or with minimal amounts of other things, and add it to the top, along with the organic material.
- ✿ It's also relatively easy to change pH in a very limited way, but this will be a continual process. This is because soil volume is vast, and it's impossible to change soil pH permanently. Your climate dictates your soil pH, so you have to be realistic in your plant selection. If your soil's pH isn't close to what you want, consider using containers or raised beds and adjust conditions there.
- ✿ You can also address compaction and drainage issues. Mulches can do this without disturbing the soil, especially with compaction. For severe drainage problems that can't be addressed by reducing compaction, consider French drains, which provide a way of wicking water away from a landscape. Keep in mind, though, that mulches will not change saturated soil conditions; those will have to be addressed in some other manner.
- ✿ What can't be changed easily? It's really difficult to change the composition, or texture, of a soil. But a product called biochar might be worth considering. Biochar is a by-product of biofuel production that has been found to be beneficial to soil and crop production and in reducing pollution. Biochar seems to have a lot of promise behind it, and although a lot of research has been done on crops, very little research has been done on gardens and landscapes.
- ✿ Nutrient toxicity is another thing that's difficult to change. This will be addressed in an upcoming lesson on fertilizers and plant nutrition, but keep in mind that it's very difficult to take things away rather than put things in, so you need to be thinking about what you're actually adding to your soil.

- ✿ It's also difficult to change heavy-metal contamination. You may be testing for heavy metals if you use your garden for growing vegetables. This will be addressed in an upcoming lesson on vegetables.

SOIL AMENDMENTS VERSUS TOPDRESSINGS

- ✿ Now that you've decided that you want to change some things about your soil, how are you going to do it?
- ✿ Consider soil amendments versus topdressings. An amendment is anything that you're working into the soil profile; a topdressing is something that just lays on top of the soil.
- ✿ There are dangers of improperly amending and overamending soils, because often, trying to amend the composition of your soil can backfire by creating a perched water table. It's important to know how water flows through different types of soils to avoid doing this.
- ✿ As you think about whether you're going to amend your soils, it's useful to think about how unamended soils work. For example, consider clay, clay loam, sand, and gravel. Clay and clay loam are smaller-textured materials, so water moves through them slower than it moves through sand and gravel, which are larger-textured materials that have a greater amount of space between their pores.
- ✿ Because water moves through gravel faster than clay loam, you might be tempted to put some gravel at the bottom of a pot or container to help wick the water through faster. But because the rate of movement is actually determined by what's on top—in this case, clay loam—the soil will be very saturated for a while, with water sitting on top. Don't put gravel on the bottom of containers and don't have two different soil textures touching each other because this slows down water and air movement and prevents roots from growing.
- ✿ In the case of organic amendments added to enrich the soil, it's possible to have too much of a good thing. When you have too much organic material that isn't naturally replaced by the ecosystem's activity, volume is lost. In other words, in landscapes that have been overamended, volume becomes less and the whole landscape subsides.

A photograph of a greenhouse interior. The structure is made of light-colored wood with a gabled roof. The walls are covered in translucent plastic sheeting, held up by numerous white vertical strings. Inside, several tomato plants are growing in raised wooden beds. The plants are green and leafy, with some small yellow flowers and green tomatoes visible. A vintage-style metal watering can with a curved handle sits on the ground in the center of the frame. The lighting is bright and even, suggesting a sunny day.

Sustainable gardeners want to reduce runoff and contamination of landscapes adjacent to them.

- ❁ Improper amendments can cause perched water tables, create subsidence, and create nutrient runoff and contamination. Why does the practice of improper amendment exist? Why are people insistent on working material into the soil?
- ❁ Most research is done on agricultural production, and soil amendment is common in annual crops, where soil can be drastically altered yearly. In contrast, permanent landscapes cannot be amended because of damage to roots, mycorrhizae, and soil structure. Rather than doing amendments, add material—such as topdressings or mulches—to the top of your soil, even in your vegetable garden.

TILLING

- ❁ Historically, tilling has been done with agriculture for centuries. There has been a lot of research on it, especially in agricultural production, that has found that tilling—which is perhaps done by gardeners as rototilling or double digging—actually damages beneficial microbes, roots, and soil structure.
- ❁ Recent research has been done on no-till approaches in production agriculture. And this type of model should also be used for vegetable gardens. Rather than tilling—which brings weed seeds up to the surface and causes erosion and compaction problems—instead you can use a coarse organic mulch to suppress weeds and prepare the soil for planting.

One of the most important lessons of sustainable gardening is to accept your soil's natural character. In doing so, you will save time, effort, and money.

By and large, you're stuck with the soil you've got, but you can improve soil drainage, aeration, and nutrition using science-based practices.

A red tractor with a green tillage implement is working in a field of young green plants. The tractor is moving from right to left, leaving a trail of dark soil behind it. The field is filled with rows of small, bright green seedlings. In the background, there are more rows of plants and a line of trees on the horizon. The sky is blue with some white clouds, and the sun is low on the horizon, creating a warm, golden light. A yellow text box is overlaid on the right side of the image.

Popular gardening practices change soil in ways that aren't sustainable for either soils or plants. Unlike production agriculture, we don't need to work organic material into the soil every time we plant, and especially not when we're planting landscape plants. By focusing on a more natural way to add organic material in our gardens—in other words, by using mulches—we can protect soil structure and nourish our plants.

READING

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QUESTIONS

- ✎ Nitrogen is the most likely nutrient to be deficient in a home landscape—it's used by plants and microbes alike. Yet most soil tests don't even test for nitrogen. Why might this be?
- ✎ Explain why tilling three inches of compost into the top three inches of soil is not sustainable in terms of soil organic matter content and why placing those same three inches on top of the soil is.



Lesson 9

The Truth about Mulch

Mulches are much more than bags of processed materials. They can be organic or inorganic, coarse or fine, chunky or smooth, living or dead. By definition, mulches include anything that covers the soil and protects it from erosion, compaction, and weed invasion. But not all mulches are created equal, and the right mulch can be the tipping point needed to transform a struggling landscape into one that's healthy and more sustainable. This lesson will review the research-based pros and cons of different mulches so that you can make an informed choice for your garden and landscape.

MULCH TYPES

- ✿ There is a plethora of mulches that exist. First, there are synthetic mulches, which include plastic mulch. There are also various kinds of fabric mulches. Some are found in tree care packages that are to be used after a tree is planted; others can be used under walkways or beds to keep weeds down. Synthetic mulches also include rubber mulches, which might be made from ground-up old tires as a way of recycling them.
- ✿ There are also living mulches, including turf and turf alternatives as well as cover crops.
- ✿ Then there are inorganic mulches—which don't break down—including pebbles, glass, stone, and pavers.
- ✿ Finally, there are organic mulches, which offer the biggest range of types of mulches, including compost, crop residues, and wood, bark, and other low-nutrient materials.

BENEFITS AND DRAWBACKS OF POPULAR MULCHES

- ✿ Fabric mulches—like the ones intended to be put down after you've planted a tree to keep weeds away—are not permeable. Thus, water movement to the soil and roots will be slow. In addition, there will be no gas exchange, meaning that oxygen can't get in and carbon dioxide can't get out.
- ✿ These fabrics do not stay a pristine surface. In fact, they are great places for weeds to grow: Water puddles on the fabric, soil and weed seeds blow onto the surface, light and oxygen are in abundance, and there are nutrients in the organic matter that lands on top. Landscape fabric of any kind could be used, at best, temporarily, but you should not use them as a permanent way of dealing with weeds.
- ✿ Rubber mulches are a great way to reuse a waste product that would otherwise end up in a landfill, and they can look great because you can have them dyed various colors. But research has found with both waste tires and rubber mulches that high levels of zinc can leech out of them and get into the soil. Even though there's not a whole lot of research on rubber mulches being used in gardens, there's so much information on them being used in other applications that we can pretty safely say that you shouldn't be using them on top of your garden soil.

- ✿ Living mulches are ground covers and other low-growing, ground-hugging plants that can help conserve soil moisture and temperatures. They are a huge aesthetic benefit to your landscape, and many people prefer to use living ground covers as opposed to other mulches because they are so beautiful. They do a lot of the same things that other mulches do: help reduce compaction, improve soil nutrition and structure, and offer a wide diversity of materials.
- ✿ But there are some drawbacks to living mulches. One is competition. The more of these plants you have, the more water and nutrients that will be needed; you're going to have to manage them more than you might otherwise. Even though they're wonderful as mulches, some of these plants—such as creeping Jennie—are so aggressive that they can displace other plants, and in some cases, they can be noxious weeds. And once they get established, it's almost impossible to get rid of some of these plants because they're so adept at growing from tiny pieces of root.
- ✿ Like the living mulches, inorganic mulches—such as pebbles—can also be attractive, and they have many of the same benefits, including reducing compaction, moderating soil temperatures, and keeping weeds out to a certain extent. Another benefit is they don't decompose, which is great for drier climates, where perhaps you don't have enough moisture to have a living mulch. If you want something larger than pebbles, you can use permeable pavers, which can be a particularly effective mulch in areas that need a permanent solution to flooding problems.



Mulch can be attractive as well as functional. For example, tumbled beach glass is a relatively expensive mulch to use, but it does look vibrant in certain landscapes.

- ❁ There are some drawbacks to using inorganic mulches. Because they're inorganic, they don't break down, at least not very rapidly, so there are no nutrients available from them, whereas nutrients are available from both living and organic mulches. Another problem is that eventually weeds can get established, even in stone mulches, and it's difficult to remove these weeds without using chemicals.
- ❁ One of the benefits of using organic mulches is nutrition. Mulches that are greener—from fresher materials—and have less wood have more nutrition. Also, organic material will contribute greatly to soil structure. It will also add greatly to soil biodiversity; there are many microbes and other small organisms that require organic material as their diet. Additionally, organic mulches will help improve plant establishment, because the microbes that live in the mulch will jump-start root systems.
- ❁ There are also some drawbacks to using organic mulches. The main one is that you have to continually reapply them because they break down. Greener materials, such as compost and coffee grounds, will disappear the fastest and have to be reapplied; woody mulches are slower, and the bark mulches are the slowest overall.
- ❁ There's also the issue of aesthetics. The most aesthetically pleasing mulches are dark and uniformly textured; they look like what you think soil should look like. There is an aesthetic bias against some organic mulches that we have to overcome because the mulches that look the worst may be the best for our landscapes.



Coffee ground mulch and compost have a lot of nutrients, as compared to shredded bark or woodchips, which are relatively low-nutrient sources.

A close-up photograph of several small green seedlings with red stems growing out of a dark, textured layer of organic mulch. The seedlings are scattered across the frame, with some in sharp focus and others blurred in the background.

Nature will slowly incorporate organic mulch at a rate that is sustainable, so your soil's organic material will continually be at ideal levels.

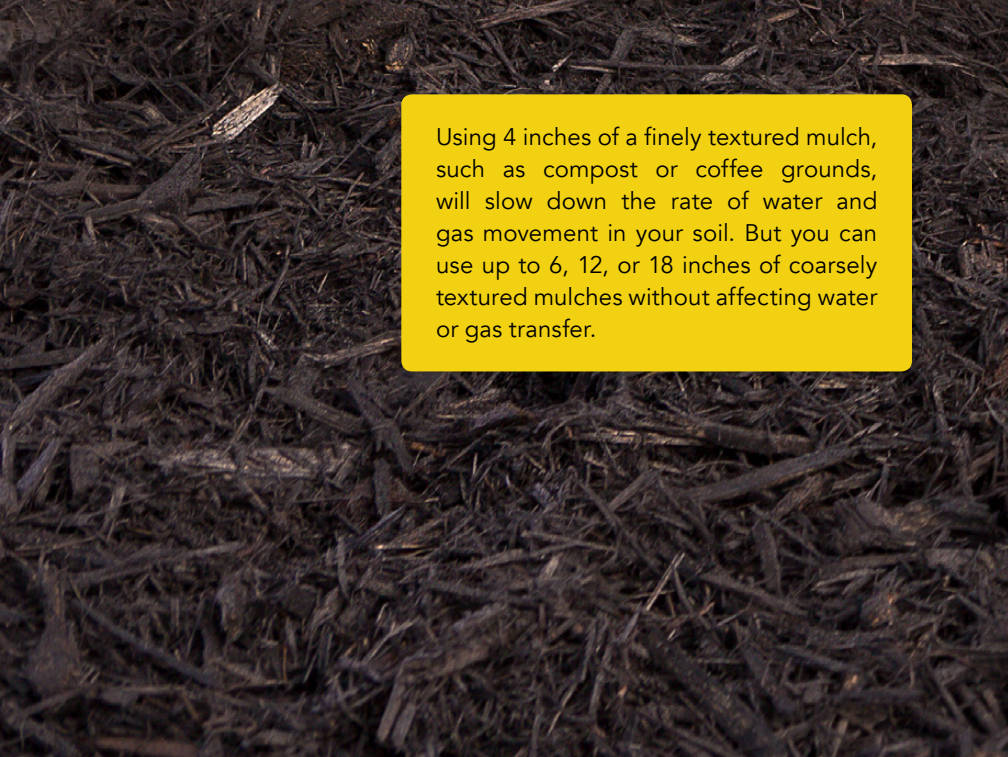
DIMENSIONALITY AND DEPTH

- ❁ Sheet mulches, such as fabrics and plastics as well as newspaper and cardboard, are very commonly used. Let's compare sheet mulches, which are two-dimensional mulches, to three-dimensional mulches, which are chunkier organic mulches.
- ❁ Lasagna gardening is a popular way to get the soil in a new garden ready for planting. This method often uses cardboard or newspaper as a layer of "noodles" and then compost or some other organic material as the "sauce." This method appeals to emotions and doesn't match up with what works well in terms of water and air movement—with which cardboard and newspaper interfere.
- ❁ There are other issues with using sheet mulches, especially cardboard, which is used often for preparing beds. One of the reasons that people tend to like cardboard, as opposed to woodchips, is that they're under the impression that woodchips are pest havens, but in fact, cardboard is the favorite food of termites. Another issue is that because sheet mulches make an impermeable layer over the soil, it's very easy for rodents to burrow under it and make tunnels. Rodents can't tunnel through woodchips—organic mulch—because they collapse.

With three-dimensional mulches, water and gas transfer are much faster than with two-dimensional mulches.



- ✿ The other thing to consider besides the dimensionality is how big the chunks are. This is important when you're trying to figure out how much mulch you're going to add and how deep you can add it. Chunky mulch is mulch that is more or less a half inch in diameter or bigger, such as woodchips, nutshells, pine needles, and corn cobs. Alternatively, sawdust, compost, and dust are very finely textured mulches, and they are much more appealing to gardeners. But the coarser the texture, the better the water and gas transfer.
- ✿ Depth is another important thing to consider. The thicker the layer of mulch, the better the weed control and the better the water maintenance. The tricky part is that deeper mulches are better for weed control because they keep the light out, but the thicker the mulch and the finer the texture, the worse the gas and water movement is, so you have to find a balance. If you want to use a more finely textured mulch, you can't use very much of it. With the coarser mulches, depth doesn't really affect either water or gas transfer.



Using 4 inches of a finely textured mulch, such as compost or coffee grounds, will slow down the rate of water and gas movement in your soil. But you can use up to 6, 12, or 18 inches of coarsely textured mulches without affecting water or gas transfer.

CONCERNS ABOUT WOODCHIP MULCHES

- ✿ The main concern that people have about woodchip mulches is that they will leech nitrogen out of the soil. And this just isn't true. It is true that if you mix woodchips into the soil, they will leech the nitrogen out because microbes are breaking down the woodchips, but as a mulch, woodchips won't change the underlying nitrogen levels of the soil.
- ✿ Another issue that people worry about is diseases—that if you use diseased wood as woodchips, you're going to transfer all of those diseases to your plants. Again, this just doesn't happen. Beneficial microbes will protect your plant's roots from diseases.
- ✿ Pests are not a problem unless the woodchips are too large. Wood-boring insects, such as emerald ash borer, can infest wood, and if you chip up wood that has been infested by emerald ash borer, make sure that it's chipped very finely so that you're not bringing any of the larvae in with your mulch.

IMPORTANCE OF LOCALLY SOURCED MATERIALS

- ✿ Think about locally sourced materials when you're making mulch choices for your landscape. Use materials such as arborist woodchips, which are great and usually inexpensive or free; recycled wood, which is good as long as it hasn't been treated with pesticides; crop residues; and greencycled household waste.
- ✿ The benefit of using locally sourced materials is that it helps remove all of these materials from the waste stream. Another benefit is a decrease in the use of packaged, transported materials.

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QUESTIONS

✎ You are creating a pocket garden that will be the focal point of your landscape. You have three choices of materials to use for mulch:

- arborist woodchips
- tumbled glass
- compost

What are the benefits and drawbacks of each? Which considerations are most important for this garden?

✎ When trees are removed from a landscape, the tree service company often will grind the stump, leaving the chips in the soil. What are the possible drawbacks of this approach, and what might be better?



Lesson 10

Planting for Survival

This lesson will focus on healthy root systems, the part of the plant that's out of sight and unfortunately often out of mind. The lesson will move the root system firmly into the forefront of your gardening awareness as you consider the best way to transplant trees and shrubs.

HISTORICAL HORTICULTURAL BACKGROUND

- ✿ Until the middle of the 20th century, all trees were planted bare root. These dormant saplings devoid of leaves or fine roots burst into full foliage within a few months of planting. Many of these trees that were planted centuries ago—stately spreading lindens and maples and sycamores—are still alive today, gracing cities and towns all over the world.
- ✿ In the last half of the last century, however, new methods of growing and selling young trees and shrubs became popular. Rather than being dug up from propagation beds and left bare, the roots are instead incased in containers full of planting media or burlap-covered clay balls.
- ✿ Planting containerized trees or balled and burlapped trees means that you're also planting a lot of other stuff, such as clay, soilless media, twine, and burlap. And there are repercussions that follow from including these materials in the planting hole. Clearly, a new approaching to planting is needed—or maybe it's not so new.
- ✿ The following planting technique is controversial, especially among nursery and landscape professionals. But current and ongoing research continues to support the need to radically change the way we've been planting trees, which too often die an untimely death for reasons to be seen.
- ✿ There are four main reasons why many transplanted trees and shrubs fail: improper soil management, poor-quality woody roots, inadequate root preparation, and the plant being installed too deeply. You will learn how to avoid these problems through the process of preparing your plants for transplanting.

PREPARING THE ROOTS

- ✿ Before you do any root washing or transplanting, you want to avoid any type of pruning of the above-ground part of the plant, except for anything that is dead, damaged, or diseased (the three Ds). Pruning at this stage will just encourage more growth later, when you want all the resources to go to the roots, not new leaves. Wait to prune after the tree is established.

- ✿ Start by pulling your plant out of the pot. If you are able to, hydrate the root ball by soaking it in a large container. This will help loosen up the organic matter around the roots so that you can more easily remove the loose material. If you don't have a chance to soak the root ball, use a soil knife or pruning saw to remove as much loose material as possible from the roots.
- ✿ Don't worry about hurting the roots. You are going to do a lot of root damage, but it's okay, because damaging roots actually stimulates them to grow back, so it's not hurting them.
- ✿ If you have the time and ability to hydrate the root ball, place it in a container of water and let it soak. It will float a little. Just make sure that there is enough water in the container to cover the root ball so that it doesn't dry out. Material will fall out of the root ball as it soaks.
- ✿ If you're doing this outside, you want to be in a cool, shaded place. This will keep evaporation at a minimum. You can leave the plant soaking in the water for days, working it with your fingers periodically to loosen the material from the roots.
- ✿ Your goal is to get all of the media off the roots and be left with the roots, which you can then either cut or straighten out, depending on how woody they are and how easy they are to manipulate. The roots will have grown in circles, and they would continue to grow in circles unless you straighten them out—which is what you should do next.
- ✿ The goal is for the roots to go outward like spokes on a wheel. That's the way roots grow—out, not down. They need to find areas where there is water, nutrients, and oxygen and areas that are away from the rest of the plant, not right under it.
- ✿ For some trees, it is best to remove all of the roots that are growing in the wrong direction: straight down. This might remove a big part of the root mass, meaning that the tree will be incredibly stressed out when it gets planted. It will need a lot of water—and a lot of care—but the new roots will grow outward, where they're supposed to, and they will be established much better.
- ✿ Don't try to plant the really long roots. Instead, cut some length off of them. Also, if any of the roots are too hard to straighten, simply prune them off.



One of the most important things to do as you're working on roots is to keep them hydrated at all times.

- ✿ If you are working with a balled and burlapped plant, the roots might be encased in clay as opposed to planting media. Because planting media is light, when it is washed off a plant, the plant doesn't lose much weight. But a balled and burlapped plant is so heavy that you will be amazed at how light it will feel once you've removed the clay soil from the roots.
- ✿ Remove the burlap. Under the burlap, the root ball will be surrounded by twine or staples, which also need to be removed. Knock off any loose clay, just as you do with planting media, and use a soil knife to cut away some of the clay if you can. Then, soak the root ball in a tub or barrel, making sure that the water covers the root ball.

If your plant's root system is just a big round mass and you simply can't get it straightened out, you could use a drastic approach called cut and spread: Make two big cuts all the way through the root ball, dividing it into four pieces, and then pull those sections apart so that it looks like a four-winged plate.



- ✿ The nice thing about clay is that it just sloughs off the roots, unlike planting media, where the roots get attached to the organic material and it's difficult to work them out of it. This makes washing clay root balls very easy. You just let nature do its work: Water hydrates the root ball and the clay sloughs off the roots and settles at the bottom of the barrel or tub, and then you can simply pull out your plant.
- ✿ Let the root ball soak in water for a day, or even a few days. Then, remove the plant from the water and wash the roots to remove any remaining clay. Make sure that you can see the crown, because you don't want to plant the crown too shallow or deep.
- ✿ You might notice some roots that have started growing off the stems that are higher than where the root crown is located. These are called adventitious roots because they are growing somewhere they're not supposed to be. These should not be planted; they should be above the ground, and you can cut them off so that they don't bother you.
- ✿ You want the crown, or flare, to be planted at grade. You might have been told to just peel the burlap back and plant the ball in the ground, but when you do that, you're planting it too deep, which leads to problems down the road.
- ✿ The next step is to pull apart the roots so that they are all radial. Cut away any roots that are pointing straight down. Also cut any roots that are knotted together and then point them out like spokes on a wheel. Cut off the ends of any roots that are extremely long. Keep working on the roots until you get them as straightened out as much as you can.

DIGGING THE HOLE AND INSTALLING THE PLANT

- ✿ Once the roots are washed off and the root system is exposed, you can begin the planting process by digging a hole. Many gardeners will dig their hole first and then get the plant ready, but it makes much more sense to get the plant ready, find out how big the root system is, and then dig the hole.

- ✿ Start by arranging the roots radially, like spokes on a wheel, in a hole that's about twice as wide as the root system but no deeper. It should look like a big, shallow depression. You might think that your plant looks like it will fall over in such a shallow hole, but you'll be surprised at how stable the plant becomes after it's planted.
- ✿ Make sure to keep the root crown at grade or slightly above grade, not below grade. Then, build a mound of soil in the center as needed.
- ✿ When you finally have your plant exactly where you want it in the hole, backfill the hole that the plant is now in with unamended native soil. Do not use fertilizer or other amendments. Whatever originally came out of that hole goes right back in, with the exception of big rocks or garbage.
- ✿ Don't press, stomp, or otherwise compact the soil; this compresses soil pores, which hold both air and water. Instead, "mud it in" with water and additional soil. This is a relatively old technique, but it's a great way of making sure the soil gets around the roots and that you're not eliminating air while you're doing it.



The time you spend in properly preparing your soil and your plant's roots will be more than repaid by the time you'd otherwise spend nursing and ultimately replacing a struggling plant.

- ✿ To use this technique, you add soil and then water. Bubbles will come to the surface, and then holes will form, so you add more soil. You keep repeating this process with water and soil until no more bubbling appears and it's just a big mud puddle. Slowly, the water will drain away, and as it does, the soil will tighten up around the roots. Gravity will do the work for you.
- ✿ At this point, if the root crown has sunken below grade, gently pull it up until it's level or above grade. If needed, you can push more soil underneath the crown and add more soil on top. Then, water it again to resettle the soil. Keep doing this until it's at grade.

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Chalker-Scott and Stout, "Bare-Rooting Containerized Materials."

QUESTIONS

- ∞ The bare-root method of preparing woody plant roots is vehemently opposed by many in the landscape industry, yet these same methods are used routinely by bonsai enthusiasts when they transplant their specimens. What might be some understandable reasons for opposition from those in the landscape industry?
- ∞ Planting at grade is generally considered crucial for tree establishment and survival. Yet some wetland species, such as willows and poplar, tolerate being planted too deeply. Why might this be?



Lesson 11

Aftercare for New Plants

Once you have healthy plants in the ground, you should consider aftercare: the materials and methods you need to use to optimize your plants' ability to survive and thrive. With aftercare, there are all kinds of heavily marketed products that you might be tempted to buy. This lesson will help you determine whether these products are necessary or even useful and teach you the best methods for maintaining a sustainable and healthy landscape.

WATERING

- ✿ All new transplants need water, even drought-tolerant species. There's no such thing as an instantly drought-tolerant plant; they first have to get their roots established.
- ✿ The single most important thing for the successful establishment of your new plants is give them plenty of water.
- ✿ Roots will grow toward water, oxygen, and nutrients, and those three things will contribute to the establishment of your plants.
- ✿ At this stage, avoid Treegator watering bags and other types of products that enclose and dampen the bark. These products are meant to go around the trunk and are full of water; the water seeps out slowly and wets the root zone. It sounds like a great idea, but the dark, moist environment that the product provides is just like being underground, so lenticels that are on the outside of the bark open up, and pests and disease can get in.
- ✿ Nothing will take the place of a gardener's eye when it comes to watering. If you see any wilting, it's time to water your plant. But if you have a poorly drained soil, more water might be exactly the wrong thing to do. So, know your soils, watch your plants, and you should know when to water them.

As long as your tree and shrubs are still alive, you can dig them up, correct any problems they might have, and replant them—during any time of the year. But if you planted a tree recently, you don't want to disturb it again and give it a double dose of transplant shock. Instead, wait a season or so.

FERTILIZING

- ✿ The roots of your plant are spread out near the surface of the soil like spokes on a wheel. You want to put the fertilizer where the roots are going to be able to access it, so fertilizer should go on top of the soil, and nature will work it into the soil. Never put fertilizer into the soil; your roots can get tip burn.

A close-up photograph of several maple leaves in autumn. One leaf at the top left is bright orange and yellow, showing signs of aging. Below it, two large green leaves are prominent, both exhibiting significant damage: they have irregular holes and numerous small, dark brown necrotic spots, which are characteristic of phosphorus toxicity. The background is a soft-focus blur of other green and yellow leaves, suggesting a dense tree canopy.

Phosphorous toxicity is very common in urban areas because we tend to add way too much of this element to our soils and it doesn't go away very quickly.

- ❁ Avoid any fertilizer that has phosphate in it unless you have extremely low levels of this particular nutrient. Research shows that urban soils have plenty of phosphorous. Phosphorous competes with iron and manganese. Excess phosphorous inhibits mycorrhizal growth. It also pollutes aquatic systems as a result of runoff.
- ❁ Don't add anything to your soil that your soil test deems adequate.
- ❁ Avoid any fertilizer that contains ingredients that are unsustainable.

MULCHING

- ❁ Instead of adding fertilizer, use mulch. Mulching, next to watering, is the second most important thing you can do for your plants.
- ❁ The best choice initially is a coarse, woody organic material, such as woodchips, nutshells, or pine needles. For example, arborist woodchips are what trees and shrubs grow under in their natural environment. Use local materials whenever possible.
- ❁ Start with a thin layer of nutrient-rich compost if you have concerns about low nutrients based on your soil test. Over time, your mulch layer will sustain a nutrient-rich layer at the mulch-soil interface.
- ❁ Add at least four inches of woody material. If you don't have that much mulch, weeds will grow better rather than worse. If there's enough light getting through the mulch, weeds will grow. But if you have at least four inches of mulch, light can't get through to the seeds. Perennial weeds will require even thicker layers of mulch.
- ❁ Don't make a mulch volcano, where the mulch starts at one level and goes all the way up the trunk of the tree. Instead, create a mulch bagel: Start with a depth of four or more inches, and as you approach the tree or shrub, decrease the depth. This is an easy way to retain water around the tree with the help of the mulch. As the mulch decomposes, you'll have to add more to keep it at a minimum of three inches. For low-maintenance sites, you can increase the depth by several inches.
- ❁ Remove weeds if they appear. Simply pulling them out is fine because mulch reduces erosion. Pulling out weeds doesn't disturb the soil.

PRUNING

- ✿ When you're ready to put your plant into the soil, remove only the diseased, damaged, and dead limbs. There is nothing else to prune, unless something was damaged during transplant. Save corrective or shaping pruning for subsequent years after transplant.
- ✿ Don't prune any small branches along the trunk; these protect and provide food for connecting trunk tissues.
- ✿ Compensatory pruning is a type of pruning that is based on the mindset that if you've pruned the roots, then you have to prune the crown the same amount, otherwise there's a huge drain on the resources of the plant. This might make sense to you—you can visualize having balance on the top and bottom—but it's the worst thing you can do.
- ✿ As soon as you prune the crown, you're going to stimulate new shoot growth, which leads to more stress on the plant. Not only is the plant trying to establish its roots, but now it has to support new leaves. You want all of the resources to go down to the roots so that they grow and establish.

STAKING

- ✿ If you use the bare-root method, you may not need to stake at all. The reason is that if you plant a root ball—the ball of clay or the planting media—it's a ball-in-socket type of thing, and the ball moves within the hole. You have to stake the plant so that it doesn't move.
- ✿ On the other hand, if you're using the hand-in-glove approach, the roots are like fingers spreading out in radial fashion, and the soil pulls around them and tightens as water drains through, so the plant doesn't move. That doesn't mean that you won't have to stake, but it means that you don't need to stake as often.
- ✿ If your environment receives a lot of wind or there is animal or people movement, those activities will cause the plant to loosen in the ground and you may need to stake. If you have evergreens that are very top heavy, you may need to stake.

- ✿ Sometimes you will have to stake, so you need to know how to stake. In a tree care kit, you will find stakes as well as the material that ties around the trunk and then around the stake. You're going to attach the stakes—two, three, or four, depending on the wind—to the trunk, and you're not going to tighten them up. You want the stake to be low and loose, just enough to have the tree be supported and still allow it to move in the wind.
- ✿ You want to see taper—where the size of the tree flares outward from the trunk to the roots—and the only way that taper develops is if the tree can sway in the wind. If a tree is staked too tightly, that prevents movement, and the tree will not develop taper. A very tall and skinny tree results, and once you take off the staking, the tree will bend over or snap off.



In the middle of a forest, trees tend to be tall and skinny. On the outer edge, trees tend to be shorter and squatter with a nice taper, which is specifically from the wind blowing them.

- ✿ How do you know when to remove the stakes? First, use the wiggle test—which involves grasping the tree and shaking it gently periodically—to estimate root establishment. You will discover that each time you wiggle the tree, it will be harder and harder to get the tree to move, which means that the roots are growing.
- ✿ Second, look for new leaf growth, which is an indication that the roots are established and can support new crown growth. This is only if you've bare-rooted the plant. If it hasn't been bare-rooted, then you're not going to get that response.
- ✿ You should remove staking as soon as possible, but definitely remove it after a year. If you do the wiggle test after a year and the tree still moves, meaning that the tree is not established, dig up the tree, correct the problems, fix the roots, and start over again. As long as the tree is still alive, you can continue to try to plant it just right so that the roots get established.
- ✿ Keep in mind that you have to take the stakes off, especially ones that are tied to the tree itself. The ties will become strangling as the tree grows. Neglected stakes will injure or kill trees.

THINGS TO AVOID

- ✿ In addition to routine staking, there are other things that you should avoid. This includes transplant supplements. For example, you might have heard that hydrogels, or water crystals, will reduce your irrigation needs because they improve the moisture holding capacity of your soil. And hydrogels do this to a certain extent, but this is not a permanent fix. Hydrogels degrade and are expensive and generally ineffective.
- ✿ Also avoid any type of vitamin B₁ supplement. The myth is that this enhances root growth. But plants make their own vitamin B₁, and you don't need to add more.
- ✿ Don't bother with packaged microbes. They don't add anything to the soil, and they're really not going to add anything to your plants.

- You also want to avoid compounds that exist for good uses but are misapplied. An example is antitranspirants, which are sprayed onto leaf surfaces to reduce the amount of water loss from them. Christmas trees, for example, are covered in antitranspirants so that they stay green longer and don't take up as much water. But you want your tree to be taking up water, and the only way to get water moving through the system is to have holes in the leaves that water leaves from.
- Also avoid root snorkels. If you look at newly planted trees, especially in urban areas, you might see a plastic tube that goes down into the ground. Some people say that the purpose of the tube is so you can add water for irrigation; other people say that it acts like a snorkel, bringing oxygen down to the roots. In any case, they're pointless. The roots are not sunk two feet below these in the ground; the roots are right there at the surface.
- Try to avoid any further soil disturbances. You want to make sure that you control erosion and runoff.

How do you know if your roots are actually growing?

There are a few ways to tell when your plant is established.

- Use the wiggle test—which involves lightly wiggling the plant periodically and noting as it becomes stiffer—to figure out what's going on underground.
- Look for new leaf growth.



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———, *The Informed Gardener*, "The Myth of Top-pruning Transplanted Material."

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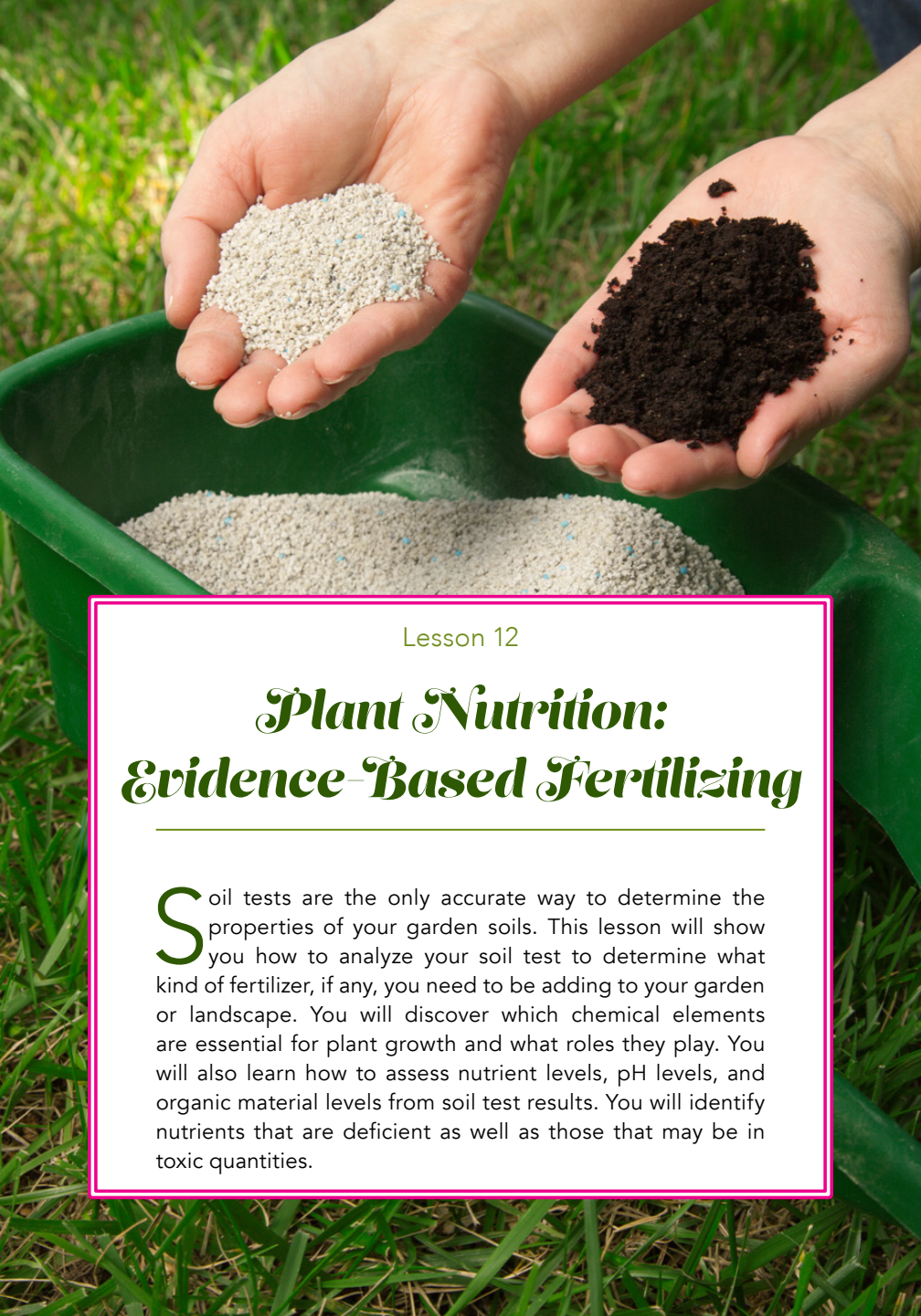
———, *The Informed Gardener Blooms Again*, "The Myth of Antitranspirants."

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QUESTIONS

- 80 There are "deep watering" systems on the market that promise to deliver water to new transplants, rather than have it intercepted by grass and other ground covers. Generally, these probes release water several inches below the surface. Is this an effective way of providing water to new transplants? Would it be effective for established trees?
- 80 You have a recently transplanted tree that you now realize was staked improperly—too tight and too high. You also realize that removing the stake could cause the tree to bend or break. How might you address this problem so that within a year your tree is freestanding?



Lesson 12

Plant Nutrition: Evidence-Based Fertilizing

Soil tests are the only accurate way to determine the properties of your garden soils. This lesson will show you how to analyze your soil test to determine what kind of fertilizer, if any, you need to be adding to your garden or landscape. You will discover which chemical elements are essential for plant growth and what roles they play. You will also learn how to assess nutrient levels, pH levels, and organic material levels from soil test results. You will identify nutrients that are deficient as well as those that may be in toxic quantities.

ELEMENTS AND NUTRIENTS FOR PLANTS

- ✿ The essential chemical elements are different for plants than for animals. There are nine macronutrients, which are nutrients that are required in relatively large quantities. The ones that every living organism on earth need are carbon, hydrogen, and oxygen. Then there are the complete fertilizer components: nitrogen, phosphorous, and potassium. The only three macronutrients are calcium, magnesium, and sulfur.
- ✿ There are eight micronutrients that we know of so far. These include mostly metals—boron, copper, iron, manganese, molybdenum, nickel, and zinc—and also chlorine.
- ✿ Then there are some unusual requirements that are only for special groups of plants. Nitrogen-fixing plants require cobalt as an additional nutrient for their nitrogen-fixation process. Selenium collectors are found in selenium-rich soils, and selenium is required for their growth. Silicon is found in the cell walls of grasses. Many succulent species have sodium as a requirement. Aluminum, arsenic, and other heavy metals may play a nutritional role that we're not yet aware of.
- ✿ There are functional designations for these nutrients. The building blocks—which make carbohydrates, proteins, fats, and nucleic acids—are carbon, oxygen, hydrogen, nitrogen, phosphorous, and sulfur.
- ✿ Another group is the cell wall strengtheners: silicone (which grasses have) and boron and calcium (which all plants have). Some elements are used for cell water management; these include chlorine, potassium, and sodium.
- ✿ There are a group of metals that are enzyme cofactors, and they include aluminum, cobalt, copper, iron, magnesium, manganese, molybdenum, nickel, selenium, and zinc. There are many toxic heavy metals that can replace these and interfere with enzyme activity.

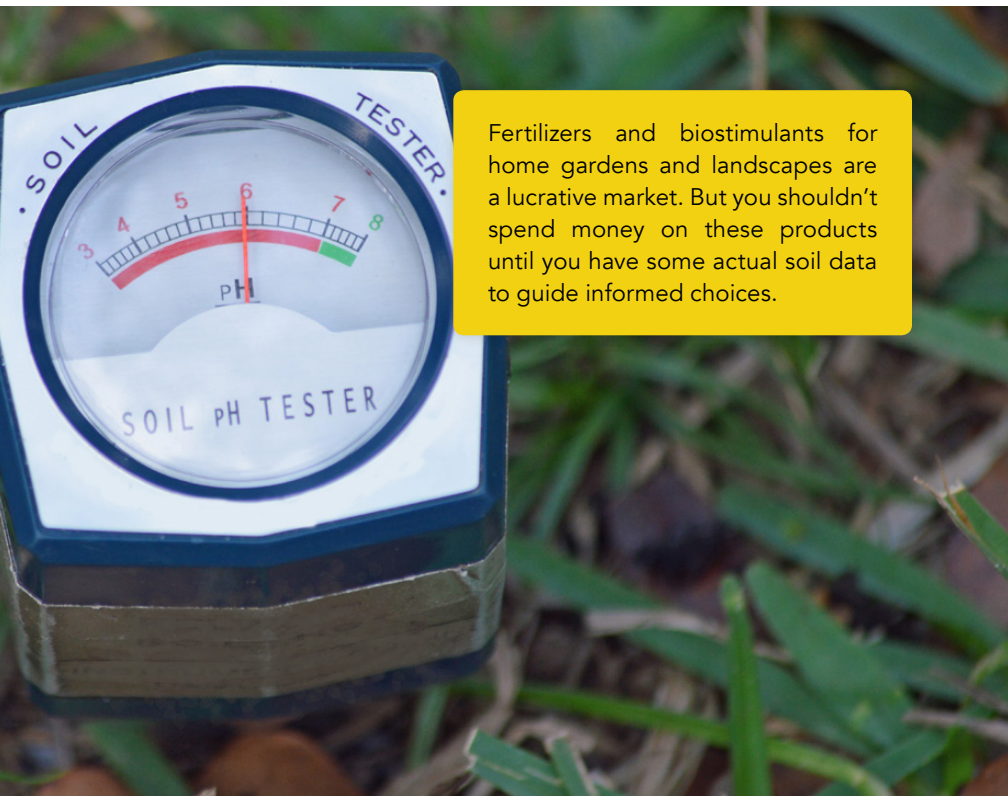
ANALYZING YOUR SOIL TEST

- ✿ It's important to get baseline soil tests so that you know exactly what you need to add to your soil, if anything. An increasingly common problem is that home gardeners think or assume they have a deficiency, so they continue to add certain nutrients without knowing what's needed, and it ends up that they have sufficient levels of the nutrient, if not moderate to very high levels.



The continued addition of already plentiful nutrients, especially phosphate, creates toxic conditions for plants and soils, organisms, and whatever aquatic system receives the runoff.

- ❁ Many soil tests lack a report of how much nitrogen is in the soil. This is because nitrogen activity in the soil changes so drastically during the day, and year, that a measurement at one point is just a snapshot in time and not relevant to what's happening in the landscape. Nitrogen deficiency symptoms are relatively easy to see, as are many other plant deficiency symptoms. If the new leaves on your plant are small and green and the old leaves are yellow, and it isn't growing very well, that tells you that if everything else is constant, your plant has a nitrogen deficiency.
- ❁ Do you have a soil deficiency or a plant deficiency? A deficiency can be pH induced or chemically induced. For example, your soil might be too alkaline for iron to be taken up, so your plant has an iron deficiency. But if none of the other plants around that plant have that problem, the plant might have a chemically induced deficiency. In other words, there is enough iron in the soil, but the problem is the iron getting into the leaf.



Fertilizers and biostimulants for home gardens and landscapes are a lucrative market. But you shouldn't spend money on these products until you have some actual soil data to guide informed choices.

- ❁ Toxicities are common in many nonagricultural soils. This is because we incorrectly apply agricultural science to garden and landscape science and add much more fertilizer than we should, based on methods of high-intensity agriculture production—which we are not doing. As you add more and more nutrients, you will have toxicities, which then can create secondary deficiencies. And this has not been studied, so it's almost impossible to find out what kind of secondary deficiencies an initial deficiency may cause.

FERTILIZER LABELS

- ❁ Fertilizer labels can be very complicated, but they are regulated, so any ingredient that is listed on the label is guaranteed to be in the fertilizer. This is true for both inorganic and organic fertilizers. If it's called a fertilizer, then it must have a legal guarantee of nutrient content. If it's not on the label, there is no content guarantee. It doesn't mean that the fertilizer doesn't contain the nutrient at all, but it usually means that there's too little of it to measure or it's so variable that it's impossible to measure.
- ❁ On fertilizer labels, you'll see three letters—N, P, and K—which stand for the macronutrients nitrogen, phosphorous, and potassium. These are reported as percent of weight in the fertilizer, such as 10-10-10, called a complete fertilizer, which has 10 percent by weight of each of those three nutrients.
- ❁ It's interesting that NPK is called a “complete” fertilizer because many nutrients are required for plant growth. So, why NPK? There's an agricultural history behind this. When you're growing crops intensively, what go deficient the quickest are macronutrients, specifically in the order of nitrogen, phosphorous, and potassium. So, historically, farmers have had to add these nutrients back into the soil in relatively large quantities.
- ❁ But this type of intense harvesting is not what happens in our home gardens and landscapes. You rarely have to add any nutrients to your soil, except maybe nitrogen, but you think that you have to add nutrients, so you tend to add more and more, without having your soil tested to let you know where you stand.

- ✿ Often, fertilizers will contain other minerals. Check the label for their presence. You don't know the content of the minerals unless they're tested for. They are reported as a percent weight, and that will guarantee the content of those minerals. But this doesn't mean that other minerals aren't also in the fertilizer.

FERTILIZER SOURCES

- ✿ There are both inorganic and organic fertilizers. Both are capable of causing pollution problems. Inorganic fertilizers break down relatively quickly, making the nutrients available quickly. Organic fertilizers tend to release their materials much slower.
- ✿ When deciding how to feed your landscape, think about whether you need a slow food versus a fast food application. If you have new plants and you want to jump-start their growth, then you want to use a fast-release, inorganic fertilizer. But if you just need to maintain your landscape, a slow-release, organic fertilizer would be better.
- ✿ Organic fertilizers increase the organic matter content of your soil. This improves drainage, water holding capacity, and soil structure. But it's easy to overdo, so check your soil test for organic matter levels.
- ✿ The risk for runoff and contamination of water sources is greatest with inorganic sources.
- ✿ When considering organic fertilizers, think about sustainability. Are they things that can be easily replaced and don't have a huge footprint? Locally produced composts—such as crop residues and residential green waste—are great. Biosolids, which is human waste that is recovered from a sewage treatment process, is also a local resource, and it is a good source of material for plant growth.
- ✿ There are also unsustainable materials. These are unsustainable because they come from other ecosystems; damage occurs when we remove materials from an ecosystem. An example is bat guano, which is a very rich fertilizer, but it comes from an ecosystem where often it's the only source of nutrients for the algae and plants that grow there.



Using organic fertilizers—especially those locally made from green waste, crop residues, and even biosolids—not only provides nutrients but also keeps waste materials out of landfills.

- ✿ Another common source is kelp, which is not necessarily a great fertilizer because it doesn't have a high nutrient content, but people like to use it because you can harvest it yourself. Kelp is the underwater forest of intertidal systems, and everything in those systems depends on that plant source, so when kelp is wild-harvested, you doom that system.
- ✿ Peat moss is very common to use both in the horticultural industry and by home gardeners. Peat comes from peatlands, which are part of the natural water purification system. Terrestrially, peatlands are the biggest carbon sink, so when peatlands are disturbed, carbon dioxide is released into the atmosphere. Plus, removing the peat destroys a unique ecosystem that has taken centuries to build. There is not another material that is exactly like peat in terms of how much water it can absorb and release, but researchers are trying to find good substitutes.

APPLYING FERTILIZERS

- ✿ The traditional way to apply fertilizer is to put it on the soil and let the roots take it up. That's the way it works in nature. But there has been an increase in the marketing of a process called foliar fertilization, which is an improper application of fertilizer. It is a great way to diagnose a nutrient deficiency, but it is not a way to feed a plant. You can also build up excessively large amounts of fertilizer, with toxic levels of elements, by foliar fertilization.
- ✿ There are other ways that fertilizer can be applied improperly. If you use too much fertilizer, you will get excessive vegetative growth. This might sound wonderful, but it isn't. Normally, plants make secondary compounds to resist pests, but when they have a plethora of nutrients, they don't make these protective materials, which leads to a reduced resistance to pests and disease. Also, using too much fertilizer at the wrong time of year can cause delayed dormancy of non-native species.

NUTRIENT TOXICITIES

- ✿ If your soil test shows that your soil contains nutrients at toxic levels, don't add more chemicals. Regardless of which nutrients are at high levels, plant a fast-growing cover crop, which will pull nutrients out of the soil. Then, remove that plant material so that the nutrients are removed with it; you can compost the cover crop, but don't put it back in the soil.
- ✿ Another way to decrease nutrient levels is a little slower but better for landscapes where you don't want a cover crop. This is by using a low-nutrient woody mulch, which, when applied on top of the soil, will be a food source for microbes, which will strip nutrients out of the soil as they're growing.

FERTILIZERS MARKETED FOR OTHER PURPOSES

- ✿ The myth is that Epsom salts, or magnesium sulfate, is a safe and natural home remedy you can use to increase plant growth. You can find information from all kinds of sources that swear by using Epsom salts for great roses, to get their turf greener, and to control pests, but there is no science behind any of this. The only time that it does any good to add Epsom salts is if you have a magnesium deficiency, and a soil test will tell you if you have one.
- ✿ Gypsum, or calcium sulfate, is used in old agricultural fields and saline environments and for breaking up very hard clay soils. But for a typical urban soil, adding gypsum will not change your soil's texture or improve its tilth, and it will not help your soil nutritionally.



BIOSTIMULANTS AND COMPOST TEAS

- ✿ Biostimulants and compost teas are not regulated, which means that there's no guaranteed nutritional analysis. They are not proven to be of any use; in many cases, they're not better than using water.

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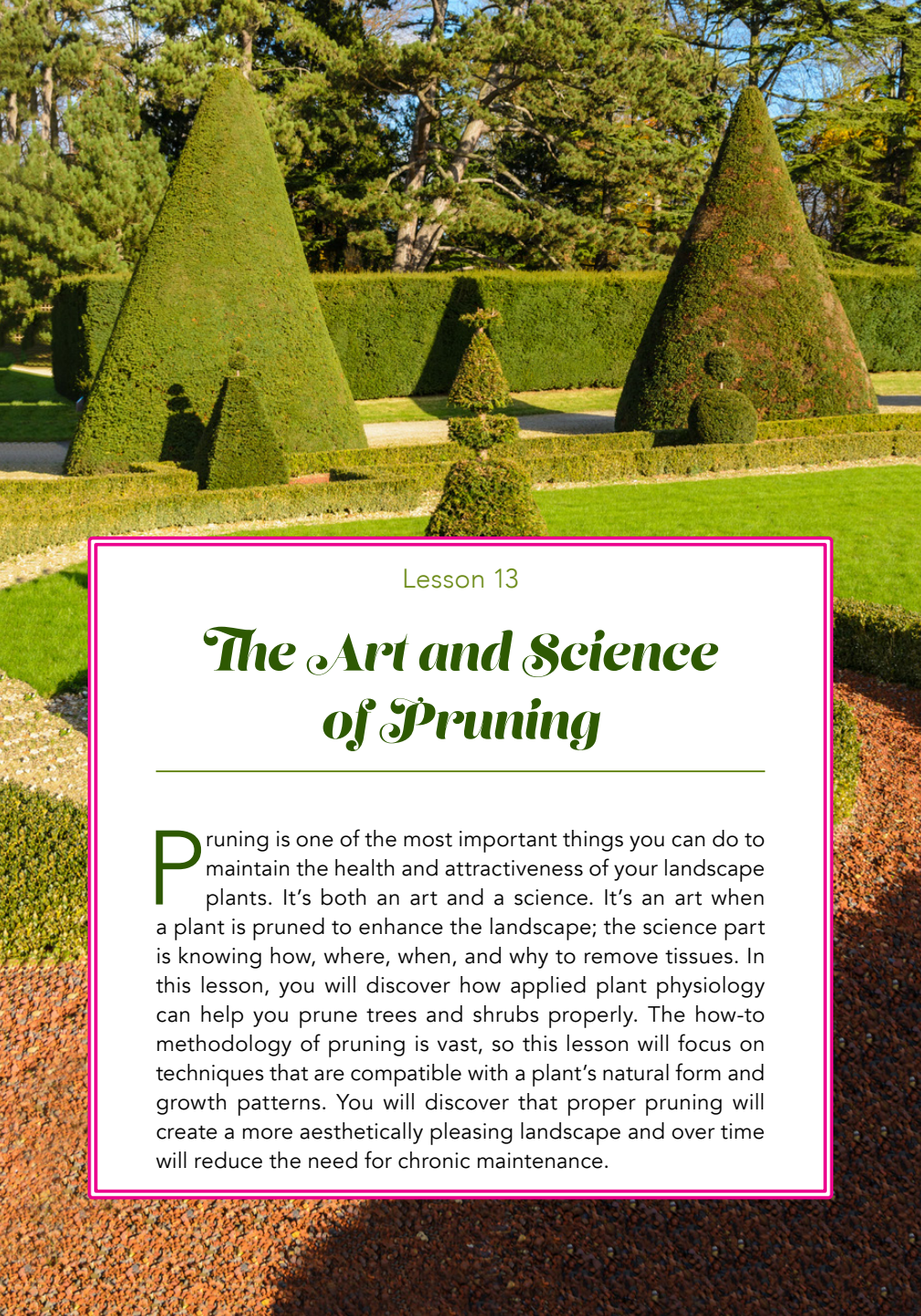
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QUESTIONS

- ✎ "Rock dust" is a heavily marketed plant supplement that purports to add trace minerals "that have been lost through the ages." Does it make sense to add this to your landscape soil? Why or why not?
- ✎ You have a young oak whose leaves show interveinal chlorosis. You suspect this might be due to iron deficiency, so you spray an iron chelate fertilizer (Fe-EDTA) onto the leaves. Sure enough, they green up quickly. What conclusions can you draw about soil levels of iron? What kind of additional information do you need, and how could you get it?

A photograph of a formal garden featuring two large, conical topiary trees made of dense green foliage. They are flanked by a low, rectangular hedge. In the background, there are more trees and a clear blue sky. The foreground shows a gravel path and some fallen leaves.

Lesson 13

The Art and Science of Pruning

Pruning is one of the most important things you can do to maintain the health and attractiveness of your landscape plants. It's both an art and a science. It's an art when a plant is pruned to enhance the landscape; the science part is knowing how, where, when, and why to remove tissues. In this lesson, you will discover how applied plant physiology can help you prune trees and shrubs properly. The how-to methodology of pruning is vast, so this lesson will focus on techniques that are compatible with a plant's natural form and growth patterns. You will discover that proper pruning will create a more aesthetically pleasing landscape and over time will reduce the need for chronic maintenance.

WHY PRUNE?

- ✿ The most common reason that homeowners prune is to maintain the size of a tree or a shrub. Many gardeners mistakenly assume that tree and shrub size can be “fixed” by pruning. But tree and shrub sizes are under both genetic and environmental control. Frequent, heavy pruning depletes a plant’s resources and opens the tissues to invasion by pests and pathogens. If a shrub has to be pruned for size more than once a year, it’s probably in the wrong place, so consider moving it.
- ✿ Training young trees is the second reason for pruning. In this way, you can correct future problems early. Never prune young trees to make them look like miniature adults. Formal pruning techniques, such as topiary, bonsai, or espalier, should be done by an expert.
- ✿ A third reason to prune is to maintain health and vigor. This involves removing competing leaders as soon as possible; removing dead, damaged, or diseased branches any time of year; and removing branches that rub or interfere with other branches, especially codominant leaders.
- ✿ A fourth reason to prune is safety. Consider the potential risk that your trees and shrubs can pose to people or property. Disease or structural defects in limbs and trunks may require removal. Choose appropriate species to avoid future problems with aggressive roots or hazardous crowns.

WHEN TO PRUNE

- ✿ When considering when to prune, consider how pruning will affect future plant growth. Natural target pruning, also known as selective pruning, is done with consideration for how the plant will respond to the pruning. The plant will remain in a natural form; it won’t look like it has been pruned.
- ✿ When you prune, you might stimulate dormant buds that are below the cut. Where they’re stimulated depends on where the cut is made; buds closest to the cut will be released from dormancy first.

A close-up photograph of a woman with grey hair, smiling as she prunes a tree. She is wearing a wide-brimmed green straw hat, a blue and white striped shirt, and tan work gloves. She holds a pair of red-handled pruning shears, cutting a branch of a tree with small green leaves. The background is a soft-focus outdoor scene with more trees and a fence.

You will know that you have become an expert pruner when a visitor looks at your freshly pruned tree or shrub and can't tell what you've done. You've attained both the art and the science of sustainable pruning.

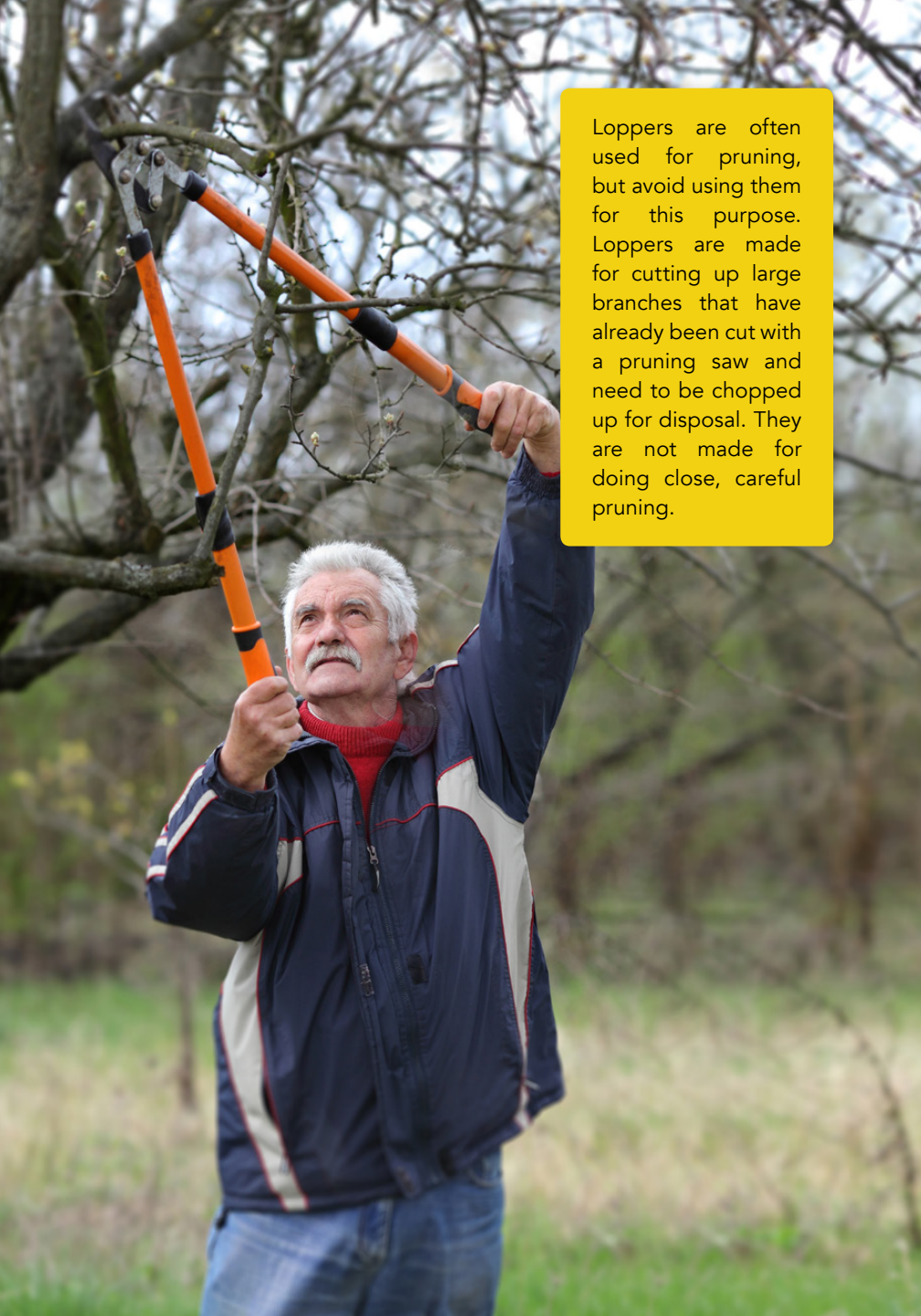
- ✿ Heading cuts, also called topping, are not recommended, with only a few exceptions. A heading cut is made between the nodes—where leaves or other branches come off—of woody tissue. When you make a heading cut, a stub remains. That stub will die and become unsightly; plus, it could be an entrance for disease.
- ✿ When you make heading cuts, you run the risk of water sprouts developing. As opposed to suckers, which come from the root system, water sprouts come up from the crown and are vigorous upright branches that are usually unattractive. When you have water sprouts, you usually have to remove them, and then more water sprouts develop. This requires constant maintenance.
- ✿ Heading cuts are appropriately made on a current year's growth to enhance flowering. This is suitable for shrubs and other multitrunk species with terminal shoots.
- ✿ The other reason that it's legitimate to make heading cuts is if you're deadheading, which involves removing a shrub or tree's flowers that have died.
- ✿ Another reason to consider making heading cuts is when using the "kill or cure" approach. This is appropriate only for those species that are naturally multitrunked. This approach is good for shrubs and small trees that have become spindly. It's basically a last resort—a way to start over when you're unsatisfied with the shape of your plant and it would be too difficult to do restoration pruning. If they are otherwise healthy, plants will respond to this approach with vigorous regrowth from the crown.
- ✿ Another type of cut is a thinning cut, which is made back to a large branch or trunk. Thinning cuts retain the natural plant growth pattern. Thinning cuts generally don't result in water sprouts. This is a type of cut that you do during the growth of trees; you remove the lower limbs as they become shaded out. Don't do this type of cut when trees are young, because the lower limbs are important to protect young bark, but older trees have thicker bark and are able to survive having those branches removed.
- ✿ You can also use thinning cuts for crown cleaning, which involves removing some of the interior branches that have become too dense to let more light in and to increase air penetration.

- ✿ You can also use thinning cuts to arborize shrubs, or to make a shrub look more like a tree. This method, which involves removing lower limbs, can be done on single-trunked shrubs that grow to a large size, such as rhododendrons. Arborizing shrubs makes them more attractive, especially in smaller landscapes, and more functional, because it improves clearance.
- ✿ There are costs and benefits associated with pruning during each season of the year.
 - ✿ Late fall/winter, when plants are dormant and have started losing their leaves, is the best time to prune from a physiological standpoint. There are few pests and diseases present. You can also see the branch structure of deciduous species. In addition, you can avoid disturbing nesting species. Pruning during this time of year is best for regrowth because it tends to have a stimulatory effect, stimulating more growth later. Avoid this in harsh climates because freezing temperatures can cause damage.
 - ✿ The spring is the worst time for regrowth. This might be good. If you want to have a smaller tree or shrub, prune in the spring because it will have a dwarfing effect. Spring pruning can also lead to “bleeding” of some species as growth resumes and the xylem and phloem are busy with water, nutrient, and carbohydrate movement, resulting in leakage that makes a plant look like it’s bleeding.
 - ✿ Pruning in the summer generally results in little regrowth, but this depends on the species. This is a good time to remove water sprouts and suckers.
 - ✿ Late summer/fall is the worst time to prune. Pruning during this time is not recommended for plants that are from less temperate climates than yours because it could stimulate growth, which leads to new growth that will be damaged by upcoming freezing temperatures. In addition, this is a physiologically sensitive time, as plants enter dormancy.
- ✿ At any time of year, you can remove dead, diseased, or damaged branches; water sprouts and suckers; and codominant leaders.

- ✿ There are a few cautions to be aware of when it comes to pruning. First, be conservative in pruning older trees because they are less resilient as they age. Second, be aware of flowering patterns. So if you have a tree that flowers in the spring, it's most likely that it forms its buds in the fall. And if you do your pruning after the buds are formed, you're going to get no flowers in the spring because it flowers on the previous year's wood.
- ✿ Don't prune after transplanting. If you prune, you will stimulate crown growth, and you want the plant's resources to be put toward rooting after it is transplanted.

HOW TO PRUNE

- ✿ The proper equipment to use for pruning includes a pair of hand pruners and a pruning saw. For smaller branches, use the hand pruners; for branches that are too big for your pruners to get around easily and be able to cut, use the saw.
- ✿ Keep cutting surfaces clean to avoid spreading disease. Although many websites recommend using bleach for this, don't use it. It's very corrosive and can ruin your tools. Instead, use materials that are labeled as household disinfectants and are noncorrosive.
- ✿ When you're trying to figure out exactly where should you make your cuts, look for the points where branches are attached to the trunk or other branches. The tissue at the point where the branch comes out from the trunk or other branch and is a little raised and rough is called the branch collar. You don't want to cut into the branch collar, because that's where natural sealing occurs. Instead, cut just above and parallel to the branch collar.
- ✿ How much you should remove when pruning varies with species, age, and environmental conditions. As a rule of thumb, about 25 percent of the foliage is the maximum you should take off per year. Restoration pruning with therefore take several years to complete. Excessive pruning will encourage water sprouts and suckers.
- ✿ Be careful if you're working with conifers, which have fewer dormant buds than angiosperms do on their wood, so if you sheer off too much, you could be left with bare wood that never truly fills in.



Loppers are often used for pruning, but avoid using them for this purpose. Loppers are made for cutting up large branches that have already been cut with a pruning saw and need to be chopped up for disposal. They are not made for doing close, careful pruning.

- There are all kinds of products that are marketed as wound treatments for trees, but trees have their own way of sealing over, in which callus tissue forms over the wound and damage is walled off internally. Cut surfaces must be exposed to oxygen for this process to function. Avoid wound paints, as these products interfere with the natural sealing process and can actually cause greater damage. The larger the wound, the longer this process takes; this is why smaller cuts are better.



Pruning can be daunting. If you don't want to be responsible for pruning your tree, call an ISA (International Society of Arboriculture) Certified Arborist to help you with this process.

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———, *The Informed Gardener Blooms Again*, "The Myth of Designer Trees."

QUESTIONS

✎ Rose growers are often told to cut canes back to an outside bud and to make a 45-degree cut through the stem. Why might these recommendations have developed? Does either make sense from a plant physiology perspective?

✎ Take a walk around a neighborhood park or other location with a large tree and find examples of the following:

- flush cuts
- candelabras or codominant leaders
- included bark

Would any of these trees constitute a hazard to people or property? If so, what should be done about them?



Lesson 14

Creating Safe Food Gardens

This lesson will give you the tools and information you need to analyze the risk of heavy-metal contamination of your garden soil. The lesson will address how some of the most common contaminants can end up in your garden soil and stress the importance of having a baseline soil test performed. Once you know whether your soil is contaminated with heavy metals, you can make decisions about how to minimize exposure through direct contact and through consumption of vegetables. Even landscapes with contaminated soils can be safely used for growing vegetables with some careful planning.

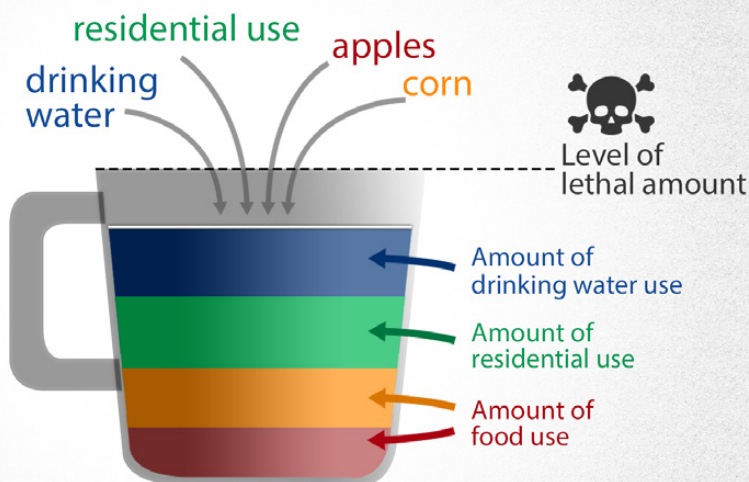
A photograph of a lush garden. In the foreground, there are several rows of leafy green vegetables, likely lettuce or spinach, growing in a garden bed. To the right of these, there are plants with reddish-purple leaves. In the background, there is a brick wall with various climbing plants and flowers, including purple and yellow blooms. A yellow text box is overlaid on the right side of the image.

It's tempting to think of your home gardens as a sanctuary where you have absolute control over what chemicals are present. But this is a dangerous delusion. Industrialization has led to the invisible problem of heavy-metal contamination in many landscapes. But knowing what your soil contains allows you to take control of the problem and reduce the risk of exposure.

PROPERTY HISTORY AND LOCATION

- ✿ Housing on land with a history of toxic deposition needs to be known. Know your history; know what used to be there. If it was an agricultural area, be aware that many pesticides used to be very toxic. If it was an industrial area, be aware that there used to be dumping of materials that were also toxic.
- ✿ Considering what might be in your soil will help you determine what types of soil tests you should do. There are many possible sources that your soil can be exposed to.

1994 Risk Cup Exposure of pesticides



The risk cup is a simple EPA graphic from decades ago that helps explain the types of contaminations you're exposed to and what you can and can't control. It is a visual way of determining your relative risk of exposure to various environmental factors.

- ⊗ If you live anywhere near a road, there will be lead in your soil from leaded gasoline from years past, old lead-based paint, and solder from old plumbing pipes.
- ⊗ Many of the older pesticides that were very effective were based on heavy metals because heavy metals are toxic to most life. Arsenic-based pesticides were very common, especially in areas where there were fruit trees.
- ⊗ Timbers used to be treated with arsenic and other types of toxic heavy metals. These old timbers are not legal in the United States anymore and should be removed and taken to a toxic waste site if they are found in a landscape.
- ⊗ Tires are also a source of heavy metals; when they break down, they can deposit zinc and lead. Consider this before using tires in your landscape, whether as a mulch or as a garden planter.
- ✿ Common activities that release heavy metals into the atmosphere, soil, and even water include manufacturing, pesticide management of orchards in the past, and pesticide manufacture and application. Unfortunately, heavy metals are there to stay. They're elemental and don't break down.
- ✿ There are many ways in which heavy metals can be introduced into your vegetable garden, including the following:
 - ⊗ atmospheric deposition
 - ⊗ contaminated compost
 - ⊗ landscaping timbers
 - ⊗ peeling paint (specifically old lead-based paint)
 - ⊗ persistent pesticides (specifically old arsenic-based ones)
 - ⊗ rubber mulches
 - ⊗ wastewater and rain barrels
 - ⊗ flooding
- ✿ You can discover potential problems for your soil by accessing online EPA and local government files for Superfund sites and other areas of heavy-metal contamination.

If your soil test shows that your soil contains a lot of organic matter, be aware that much of the organic matter in your soil will bind heavy metals. Also be aware that you may need to specifically request having your soil tested for heavy metals and aluminum.



HEAVY-METAL CONTAMINATION IN YOUR GARDEN

- ✿ There are some general rules of thumb about heavy-metal contamination in vegetable gardens.
 - ⊗ We ingest heavy metals from our diet. Vegetables and cereal are the primary sources of lead. Cereals and root vegetables are the primary sources of cadmium. Heavy metal levels are higher in urban-grown vegetables than in rural-grown ones.
 - ⊗ There is no predictable pattern when it comes to airborne metals in terms of how plants take them up. It varies among species, among tissues, and with life stages. It also depends on how easily your soil releases metals. Some soils bind tightly to metals while others don't. Sand and silt do not bind nutrients or heavy metals; soils with more clay and soils with a lot of organic matter will bind heavy metals.
 - ⊗ Metals are more mobile in acidic (low pH) soils. Metals are also more mobile in sandy soils. Metals are less mobile in clay soils.
- ✿ When considering the relative safety of vegetables that might be grown in contaminated soils, there are some guidelines that will help you understand what you can grow and consume safely based on what your soil conditions are like. The uptake of heavy metals is species-specific, and sometimes it doesn't occur because the plants are able to exclude them.
- ✿ But if uptake does occur, then the roots are most likely to be contaminated. If this happens, you might not want to grow beets, carrots, or other foods whose parts you would be eating grow below ground.
- ✿ Stems are less likely to be contaminated. The stems of rhubarb, for example, would be the most edible part of the plant.
- ✿ Leaves can be contaminated. Leaves that are red are often more contaminated than those that are green. Fruits are less likely to be contaminated. The exception to this is zucchini, which accumulates certain heavy metals.

- ✿ There are other complications, in addition to complications from soils, species, and tissues. Earthworms increase heavy-metal uptake. Chelating fertilizers increase accumulation. Phosphate fertilizer increases accumulation. And compost and other organic material binds heavy metals, reducing uptake.
- ✿ There are some other concerns as well. Uncertified organic products have been found to contain excessive lead and cadmium. Kelp-based fertilizers are often high in cadmium and other heavy metals. And fruits and vegetables that are found near roadways have been found to receive more airborne lead and other heavy metals than fruits and vegetables found farther away from roadways.

STRATEGIES TO REDUCE YOUR EXPOSURE TO HEAVY METALS

- ✿ Fortunately, there are some strategies to help minimize your exposure to heavy metals.
 - ✿ It is important to have your soil tested—not just for nutrient values, but for health values for you. In particular, have your soil tested for specific heavy metals.
 - ✿ When you're working outside, if you know that you have heavy metals in your soil—or even if you don't—wear a dust mask and gloves to reduce your direct exposure, especially if you're going to be doing a lot of soil turning.
 - ✿ Use untreated wood and other safe materials for beds. Pressure-treated lumber, these days, is fine. The older pressure-treated lumber is called CCA (copper, chromium, and arsenic) and is no longer sold but is still around. The metals leech out of the wood and into the soil as the wood decomposes. Better choices are untreated wood, especially species that are naturally resistant to rot, such as cedar boards; concrete and other inorganic materials, which are stable and sturdy, such as brick; and recycled plastic timbers, which look like wood and maintain their shape and structure.
 - ✿ When you're filling beds, if you are building raised beds, make sure that you only use certified composts and soil mixes. Unregulated composts might contain industrial waste, lead-based paint products, pesticide residues, or sewage sludge. There are better choices than unregulated compost. Look for composts that have

been certified as pesticide- and heavy metal-free. Look for the U.S. Composting Council seal, which means that there are no pesticides or heavy metals in a product.

- ⊗ Plant in containers or lined raised beds with new soil if your landscape soil is contaminated. To line your bed, put down some kind of plastic membrane, build the bed, and then add clean landscape soil for planting.
- ⊗ Only use coarse organic or inorganic mulches. Try to avoid rubber mulches, which are made out of old tires, which contain heavy metals, including zinc, chromium, and cadmium. As the mulch breaks down, these metals are released into the soil. Especially avoid rubber mulches if you're trying to raise vegetables for human consumption.

A photograph of a garden with wooden raised beds. In the foreground, there are green plants and red flowers. In the background, there is a stone wall and a red roof. A yellow text box is overlaid on the image, containing text about home gardening and a list of points.

Home gardening is one of the most gratifying types of urban horticulture. But remember some important lessons from this lesson when planting edibles:

- You should identify exactly which metals are present in the soil and, if possible, discover and control the contamination source.
- You can make some informed choices about whether you can still use your garden soil for growing vegetables based on the metals of interest and your plant choices.
- You can construct some creative alternatives if you decide the risk of using the native soil is too great.

- ⊗ Avoid planting near roadways. If you have the opportunity to plant behind your house rather than in front of your house, near a roadway, do that. If you don't have any other place to plant than near a roadway, a raised bed will help reduce contamination from the underlying soil.
- ⊗ Use only tap water or rain barrel water for watering vegetable gardens. Note, though, that rain barrel water can be contaminated by roof materials, especially asphalt, or moss removal products, which can contain zinc or copper.

READING

Cogger, "Raised Beds."

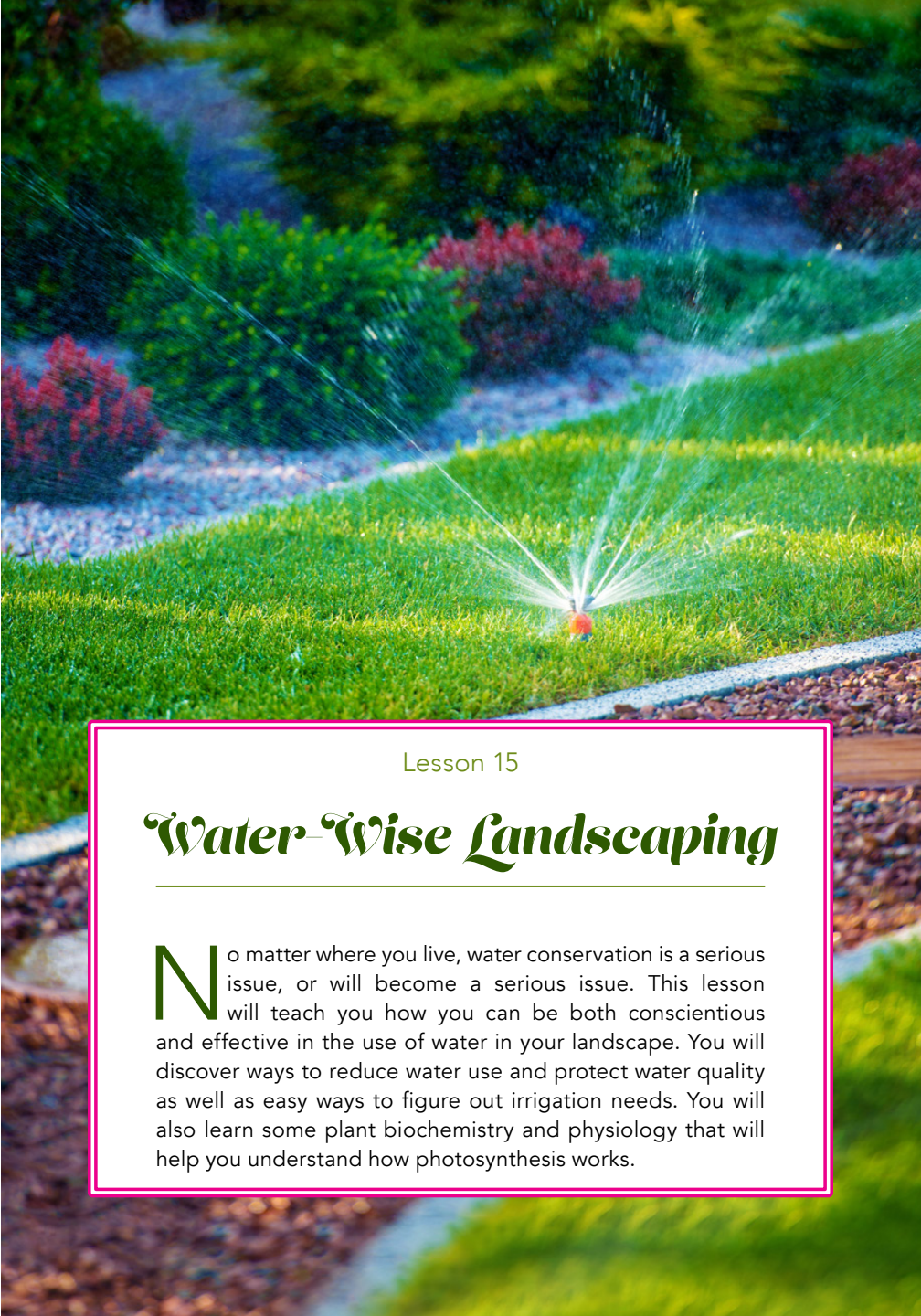
Chalker-Scott, *Rubber Mulch Use in Home Landscapes*.

———, *Safe Handling and Use of Rain Barrel Water in Gardens and Landscapes*.

———, *The Informed Gardener Blooms Again*, "The Myth of Protected Preservatives."

QUESTIONS

- ∞ Based on the specific conditions of your home property, devise a planting plan for a vegetable garden that takes into consideration the following:
 - exposure to lead from old paint or leaded gas
 - exposure to airborne contaminants based on prevailing winds
 - exposure to any heavy metals based on history of property and surrounding area
- ∞ Collecting rainwater from roofs is a popular method of supplementing irrigation needs for gardens. What are the possible sources of contamination in roof-collected water?



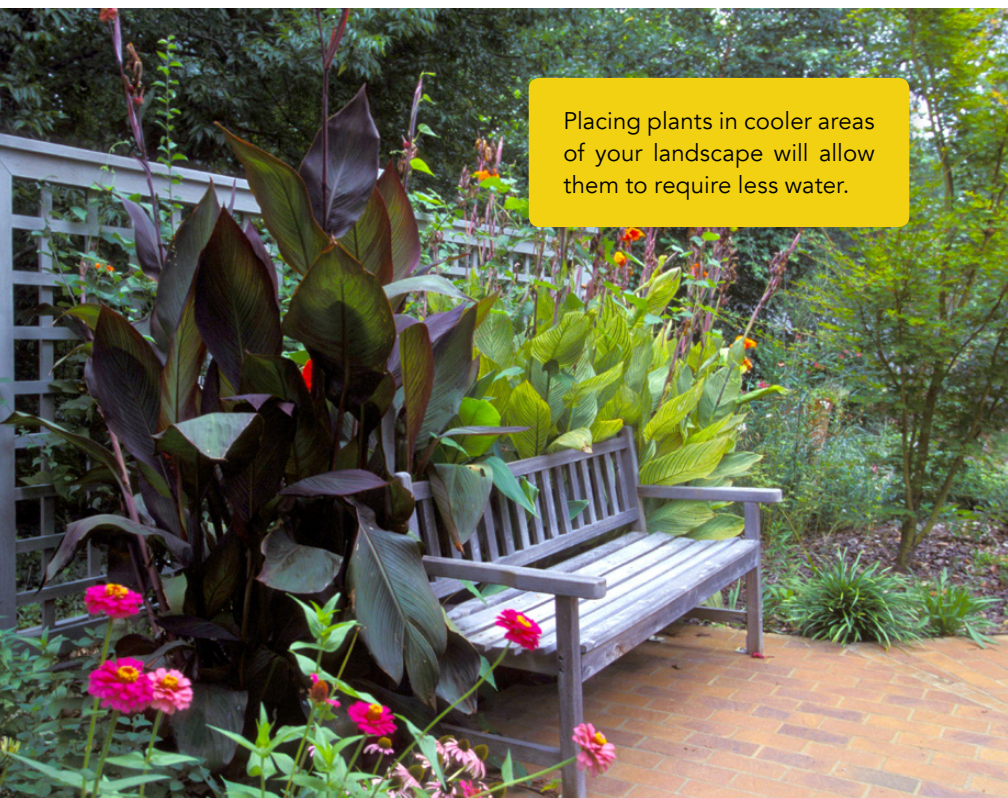
Lesson 15

Water-Wise Landscaping

No matter where you live, water conservation is a serious issue, or will become a serious issue. This lesson will teach you how you can be both conscientious and effective in the use of water in your landscape. You will discover ways to reduce water use and protect water quality as well as easy ways to figure out irrigation needs. You will also learn some plant biochemistry and physiology that will help you understand how photosynthesis works.

BASICS OF WATER-WISE GARDENING

- ❁ Water-wise gardening has a few components: reducing both the use of and the evaporation of water. In other words, it involves reducing how much water plants are getting and reducing how much water is lost, either from the plants themselves or from other surfaces.
- ❁ There are some great design modifications you can consider. To reduce the use of water, consider using more hardscape, such as pathways of different types of pavers and decks and patios. Also consider using grass islands rather than having grass as the bulk of your landscape. In addition, consider creating hydrozones—collections of plants that have the same water requirements—in your landscape. To reduce the loss of water, consider structural components, such as windbreaks—which are linear plantings of trees and shrubs designed to reduce wind, which strips water from plants—and shading, which reduces temperature and therefore reduces evaporation.



Placing plants in cooler areas of your landscape will allow them to require less water.

- ✿ You can select plants that will thrive in water-conserving landscapes. Xeriscaping is a landscaping method that implements water-saving techniques. Using this technique, you might think that you need a small number of plants in your landscape, but it actually should be full of plants. Consider succulents, which are traditional xeriscape plants. But be careful because even though succulents can survive with very little water, they often will use as much water as you give them.
- ✿ You can also choose plants with water-conserving characteristics using certain morphological cues. First, consider plants that have highly dissected leaves, which reduces evaporation compared to solitary blades due to having less surface area. Next, consider plants with leaves that are grayish blue or grayish green, because they have a waxy cuticle that helps reduce water loss. Also consider pubescence, which, for a succulent, materializes as fuzzy leaves, which reduce the stripping off of water through heat or wind. Finally, consider plants that have small leaves that are packed together tightly; this dense packing reduces the amount of water that evaporates from the leaves.
- ✿ You need to reconsider your lawn. This is difficult for many homeowners to even think about. Part of reconsidering your lawn is accepting that it's not always going to look beautiful. The reason we have problems with our lawns is because turf uses the most water of any landscape plant. Keep in mind that you can let your lawn go dormant if water or temperatures are not ideal. Alternatively, think about how you can change having a lawn into a way that's more sustainable. You can replace the lawn without destroying the soil by mowing it flat during the dormant season when it is brown and then mulching it deeply with woodchips, letting it sit until the turf is gone. Then, you can plant water-conserving plants.
- ✿ You need to think about soil management. Specifically, keep weeds out. Weeds use water—sometimes more water than your desired plants. Weeds can be dealt with by keeping exposed bare soil covered with mulch, plants, or hardscapes.

One of the biggest leaps for sustainable gardeners to make is to reconsider the importance of an emerald green lawn in their overall landscape plan. Lawns require more water, more fertilizer, and more management than many other landscape plants. By rethinking our lawn needs, we can limit lawns to those uses and locations that are most important to have a lawn and replace the rest with alternative plantings or even hardscapes.



PROTECTING WATER QUALITY AND AVAILABILITY

- ✿ Water-wise gardening means protecting water quality as well as availability. One way to do this is by managing storm water to reduce the soil erosion, sedimentation of downstream water, and scouring of your landscape that occur during big rain events. For example, to avoid scouring, use woodchip mulch, which, once established in your soil, serves as a permeable mat that keeps water going through and keeps the soil in place.
- ✿ Also consider additional water sources for your garden and landscape. To reduce water usage from your garden hose, consider capturing and reusing water from your sump pump, commonly found in basements of houses. Similarly, if you have an air conditioner, the condensate that comes from the air conditioner is a relatively clean source of water, so you could use it in your garden. In addition, you can use rooftop-collected water through rain barrels. Be careful about using this water, though, because it might contain chemical or fecal contaminants. This water will probably not hurt your plants, but it might hurt you.
- ✿ Consider reducing the use of fertilizers, especially phosphates.
- ✿ Consider reducing the use of pesticides, which have unintended impacts on aquatic systems.
- ✿ Consider limiting the use of rich organic material, which is a source of nutrient contamination.

MONITORING WATER NEEDS AND USAGE

- ✿ When you have a mixed landscape, you just can't predict when to water or how much water you're going to need. To figure this out in a mixed landscape, find certain indicator plants, which will wilt first. When you see wilting, water right away. Don't wait, because if you wait, you could get terminal wilt, and plants don't recover from that.
- ✿ At the same time, if you see wilting, make sure that it isn't due to other soil problems. A common cause of wilting in landscape plants is overwatering. If the soil is waterlogged, there's no oxygen. Then, the roots aren't taking water up to the leaves and they wilt—not because the soil has too little water, but because the leaves have too little water.

- ✿ The finger test, which can be used for soil texture, can also tell you about water conditions of the soil. If you can form an intact ball with the soil and it leaves a stain on your fingers, the soil is moist. On the other hand, if you can squeeze water out of the ball, it's too wet.
- ✿ Don't bother with moisture probes, which you stick in the soil to determine its moisture. The roots of plants go way beyond one spot in the soil, so what's happening in one spot may not be the same as another spot.
- ✿ Don't bother with evapotranspiration (ET) coefficients, which are determined by a mathematical model that predicts how much water needs to be used by particular plants. This process works well for monoculture crops and golf courses, but it will not work in your landscape.

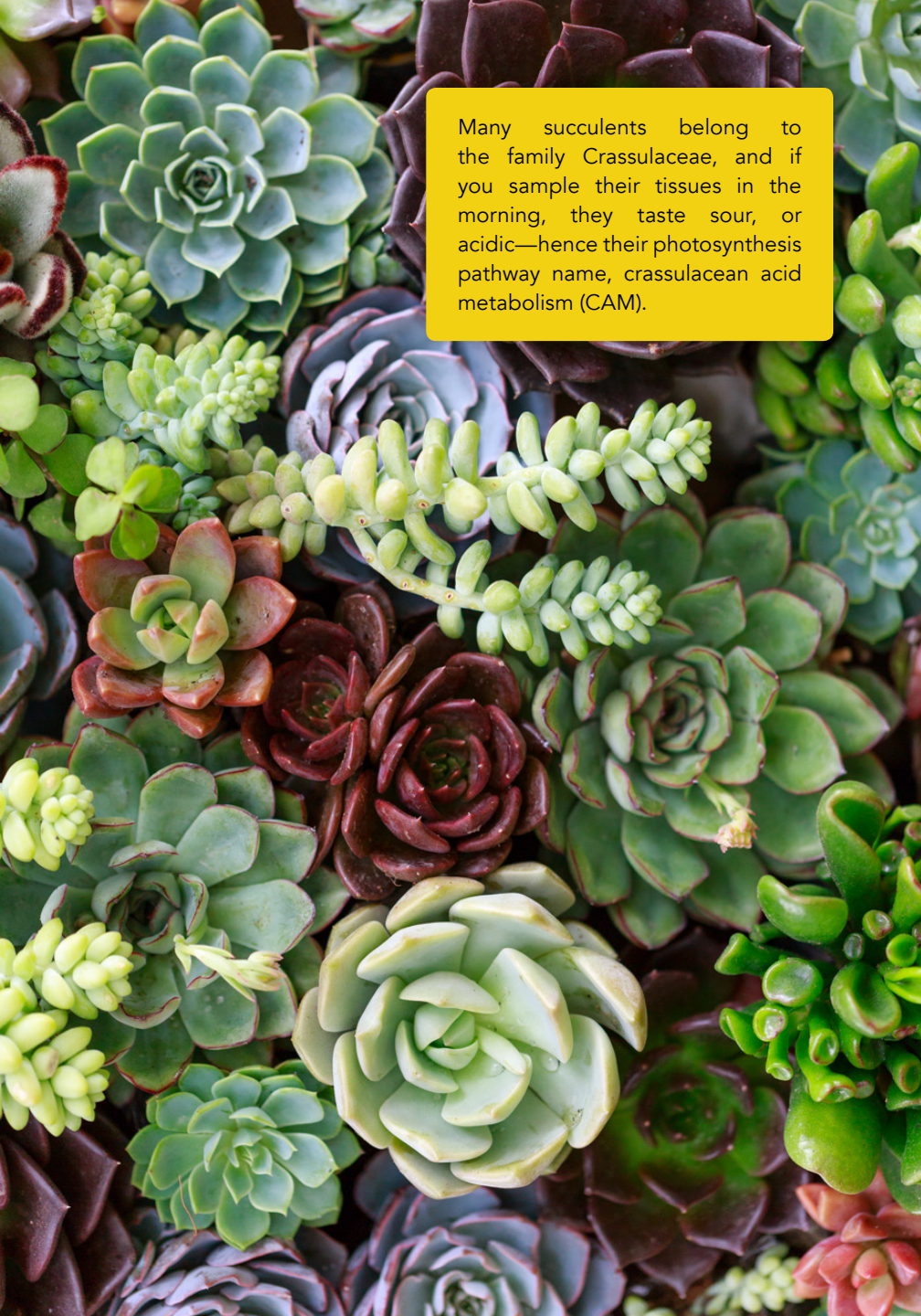
Even if water is clean and plentiful where you live, we all have a responsibility as sustainable gardeners to conserve and protect this resource. Water doesn't recognize boundaries, and the benefits of water-wise gardening choices extend far past your property lines. View your activities through the lens of water conservation and create gardens and landscapes that are both sustainable and beautiful.



PHOTOSYNTHESIS PATHWAYS

- ✿ Photosynthesis involves carbon fixation, in which the gas form of carbon dioxide is taken up by plants and made into a solid form, which then makes its way up the food chain. The enzyme that's responsible for fixing carbon into a solid form is ribulose-1, 5-biphosphate carboxylase/oxygenase (RuBisCO), and for this reason it is the most common enzyme on earth.
- ✿ During carbon fixation, carbon dioxide is brought in, and RuBisCO sticks it onto a 5-carbon compound, making a 6-carbon compound, which immediately splits into two 3-carbon compounds. Because the first product of this carbon fixation process is a 3-carbon compound, it's called C3 photosynthesis. All plants do C3 photosynthesis at some level with some modifications, but C3 photosynthesis is common in temperate zone plants.
- ✿ C3 photosynthesis doesn't do very well in hotter areas. And the reason has to do with oxygen problems. When oxygen binds to RuBisCO, it messes up the ability of it to bind to carbon dioxide. And the more oxygen you have, the more likely this problem is to occur. The brighter it is, the hotter it is, the faster that reaction goes and the more likely RuBisCO is to bind to oxygen.
- ✿ This is called photorespiration, which basically cuts photosynthesis off. The RuBisCO binds to the oxygen, which then binds to the 5-carbon compound, but now it's not a 6-carbon compound because it's bound to oxygen. This 5-carbon compound basically does nothing, so it has to be fixed biochemically, which takes energy, and eventually it will be ready to go into the RuBisCO system. At the same time, RuBisCO is busy binding oxygen, so it can't bind carbon dioxide. These plants become less and less efficient in terms of fixing carbon.
- ✿ To fix this problem, many grasses and plants from tropical areas have a modified version of the C3 pathway called the C4 pathway—which is the same as the C3 pathway, but with a few extra first steps. These plants are photosynthesizing, but when the carbon dioxide comes in, rather than binding onto RuBisCO, it binds onto phosphoenolpyruvate (PEP) carboxylase.

- ✿ PEP carboxylase is not part of the photosynthetic pathway, so it carries that bound carbon somewhere else—into the leaf—and fixes it into a solid form, which can't be used in photosynthesis, and then takes it to the bundle sheath cells, which surround the veins in C4 plants. Once the PEP carboxylase gets inside, it releases the carbon that it has bound, which is now in there as carbon dioxide, and this is where you find RuBisCO.
- ✿ RuBisCO is hidden away from oxygen in these bundle sheath cells, so it's a carbon dioxide-rich, oxygen-poor environment. And that's great in terms of being able to photosynthesize without the problem of photorespiration. So, even when it's dry, hot, and bright, there's lots of oxygen around because there's lots of photosynthesis going on. The oxygen itself is physically separate from where the enzyme is, so the C4 plant is able to photosynthesize much more efficiently than the C3 plant.
- ✿ When you compare the two pathways, even though C3 plants require less cellular energy to photosynthesize, when they're photorespiring, they lose so much energy that they could actually lose weight over time. So, although the C4 pathway requires more energy at the beginning, it actually saves energy because of the reduction in photorespiration.
- ✿ The succulents, which are found in environments that are hot and dry, have a third way of reducing photorespiration problems: the crassulacean acid metabolism (CAM) pathway, which helps these plants retain water and still allows them to photosynthesize.
- ✿ This pathway is just like the C4 pathway. It has those extra steps at the beginning, where carbon dioxide binds with PEP carboxylase, and the carbon is carried to wherever the RuBisCO is. And while the C4 plants had this spatial separation of the enzyme from oxygen, the CAM plants have a temporal separation.
- ✿ Because these plants are in such hot, dry environments, they close their stomata down during the day when water is very low and it's very hot. But when the stomata are closed, carbon dioxide can't get in, so the plant can't photosynthesize. These plants overcome this problem by having their stomata open at nighttime to let carbon dioxide in and oxygen out.



Many succulents belong to the family Crassulaceae, and if you sample their tissues in the morning, they taste sour, or acidic—hence their photosynthesis pathway name, crassulacean acid metabolism (CAM).

- ✿ RuBisCO requires light for its activity, so it won't work at night. But PEP carboxylase works at any time. So, the carbon dioxide comes in, and PEP carboxylase grabs onto it and stores it. In the morning, the stomata will still be open for a while. RuBisCO is active because the sun has come out, so PEP carboxylase has already released the carbon dioxide. RuBisCO can bind it, photosynthesis starts, and sugars are collected. And that goes on until it gets too hot and dry, and then the stomata close down. It's a harsh environment, but these plants can retain water through this process.

READING

Chalker-Scott, *How Plants Work*, ch. 4.

———, *The Informed Gardener*, "The Myth of Hot-weather Watering."

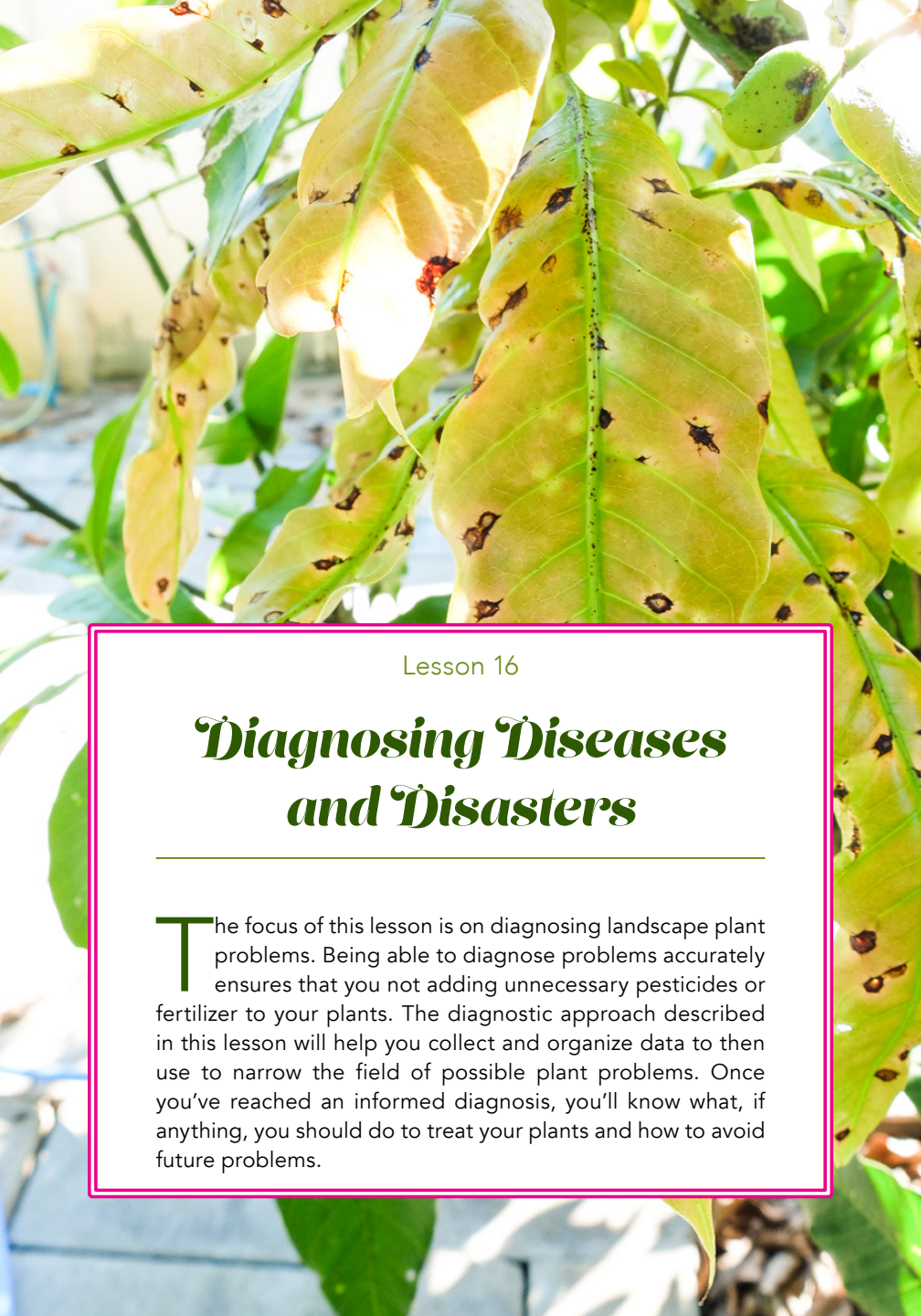
———, *The Informed Gardener Blooms Again*, "The Myth of Wilting Leaves."

———, *The Informed Gardener Blooms Again*, "The Myth of Winter Watering."

———, *The Informed Gardener Blooms Again*, "The Myth of Xeriscaping."

QUESTIONS

- ✎ Visit a nursery or botanical garden and look for plants that have xerophytic characteristics: pubescence; thick cuticles; and small, thickened leaves. Write down the names and look them up on the internet when you get home. Were you correct in your presumption that these plants are from water-limited sites?
- ✎ Why is a vast, green lawn such a persistent mainstay of home landscapes? What arguments would be most persuasive to encourage people in your town to reconsider their lawns?



Lesson 16

Diagnosing Diseases and Disasters

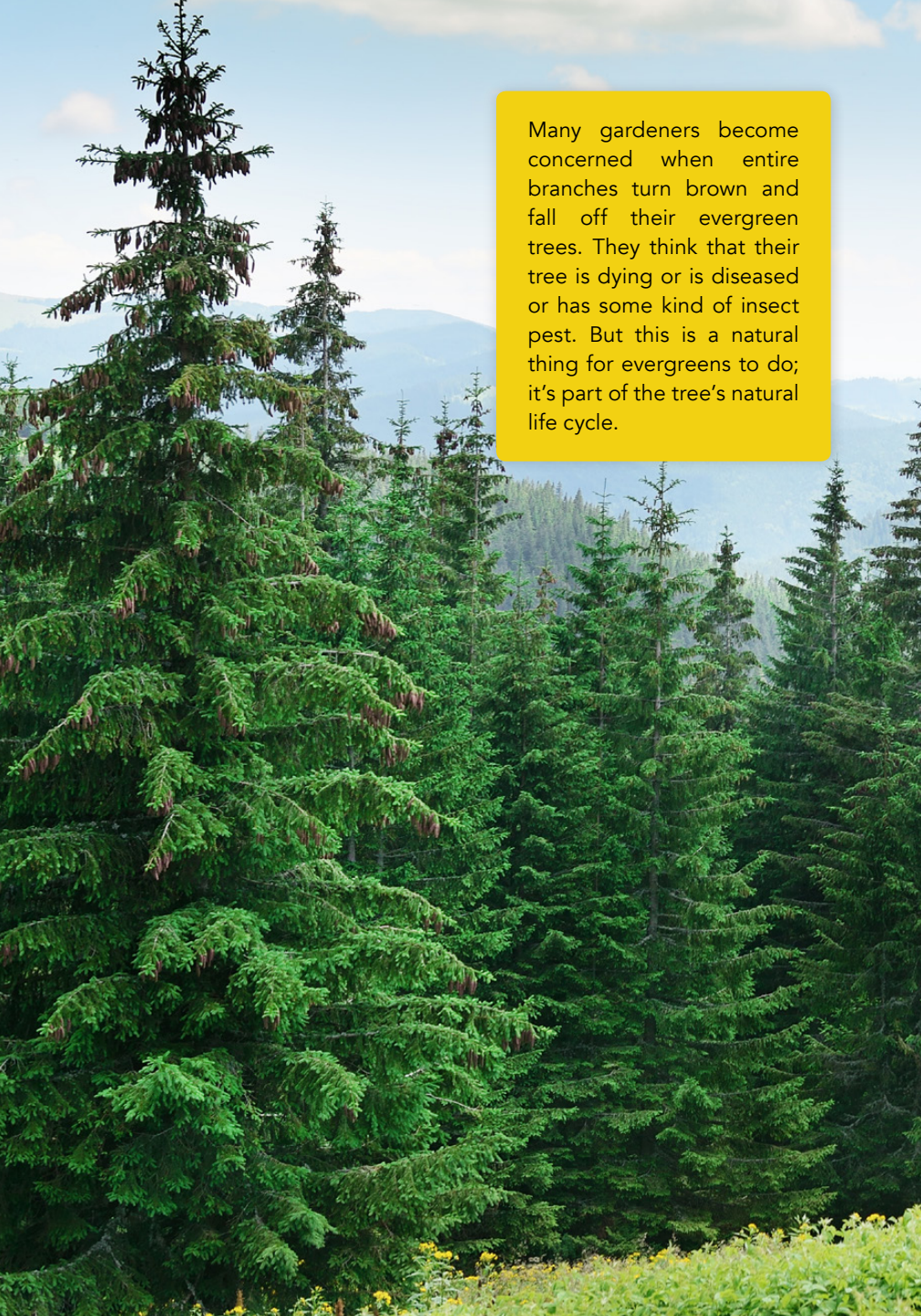
The focus of this lesson is on diagnosing landscape plant problems. Being able to diagnose problems accurately ensures that you not adding unnecessary pesticides or fertilizer to your plants. The diagnostic approach described in this lesson will help you collect and organize data to then use to narrow the field of possible plant problems. Once you've reached an informed diagnosis, you'll know what, if anything, you should do to treat your plants and how to avoid future problems.



Plants die most often from poor horticultural practices, not from pests and disease.

DIAGNOSING PLANT PROBLEMS

- ✿ To properly diagnose plant problems, first examine the plant and the landscape. You have to see the entire plant—not just a single leaf—and you have to see it in its landscape. Then, define the problem. Specifically, examine the root zone and the leaves, which are two areas that you can find clues. Next, identify the possible sources of the problem, and finally formulate solutions to fixing the problem.
- ✿ Examine the plant to determine that a problem exists. Identify what type of plant it is. Establish what a “normal” plant would look like at this particular time of year. Learn about the type of care and environmental conditions that the plant requires to thrive. Keep in mind that just because a plant may look like it’s failing, it doesn’t mean that it actually is. This is often the case with evergreens. In addition, sometimes a plant or tree may in fact be failing, but in a way that is completely natural and expected based on life span.
- ✿ After figuring out what your plant is and whether it actually has a problem, make sure you can describe the abnormality, both for your own knowledge and to anyone you might be asking for advice. This involves looking for symptoms of damage and signs of insects or other types of biotic factors.



Many gardeners become concerned when entire branches turn brown and fall off their evergreen trees. They think that their tree is dying or is diseased or has some kind of insect pest. But this is a natural thing for evergreens to do; it's part of the tree's natural life cycle.

- ✿ Next, examine the entire plant in its environment. You can't diagnose from a picture. If it isn't possible for you to see the information firsthand, it makes it much harder to tell what the problem might be.
- ✿ Then, determine the site history. Trees and shrubs take a while to die, so there could be significant issues with soil management from years before that won't manifest until years afterward in the plant. These issues include road building or repaving or foundation excavation, soil amendments, and fertilizer/pesticide usage.
- ✿ Finally, determine how the plant was installed. In other words, how was it planted? Often the reason a plant is failing is because it was not planted properly.

NONLIVING STRESS FACTORS

- ✿ There are a few nonliving stress factors that can be seen when examining the root zone.
 - ⊗ Look for surface roots, especially circling and girdling roots. Roots should be going out like spokes on a wheel, and they go far beyond the crown of the tree. You don't want to see them circling and girdling the trunk.
 - ⊗ Also look for suckers on a single-trunk species because this might indicate a problem underground. Finding suckers is a good indication that you need to examine your tree's environment for possible stressors.
- ✿ There are also nonliving stress factors on leaves.
 - ⊗ Wilting is one of the best diagnostics there is. If your plant has wilting leaves, it doesn't necessarily mean that it needs more water. It means that the leaf doesn't have enough water, either because the soil is dry or it is too wet. There are many stresses that are water related. If the leaf is distorted, such as warped or cupped, this is often a temperature-related issue—the environment being either too hot or too cold—or sometimes a nutrient-related issue, such as an imbalance.

☼ Look for discoloration.

- Chlorosis happens during senescence. When leaves are getting ready to fall, they change from green to yellow, and chlorosis is the yellow color. In other words, chlorosis is the green part going away and the yellow part remaining. This is normal but could be abnormal if it happens out of season. Another type of chlorosis is interveinal chlorosis, where a leaf has green veins and the tissue in between the veins is yellow. This could be caused by a lack of nutrients, such as iron and manganese.
- Necrosis, which is tissue death, is generally due to water stress, although it can be from early senescence. Necrosis manifests itself in leaves that are brown and crinkly, which is due to dryness. If the browning is all on the tips and the margins of the leaves, this is a diagnostic for drought stress. Water loss first occurs in the edges of a leaf. After that part dies, the damage then works its way back through the entire leaf. You can tell how severe a drought has been just by looking at the amount of tissue death a leaf has.
- Leaf reddening could be due to water stress if it's out of season, or it could be from a variety of other stresses. But it's normally part of the senescence response: When leaves are turning color and getting ready to fall off, many turn red before they turn yellow, and before they turn brown and drop off.

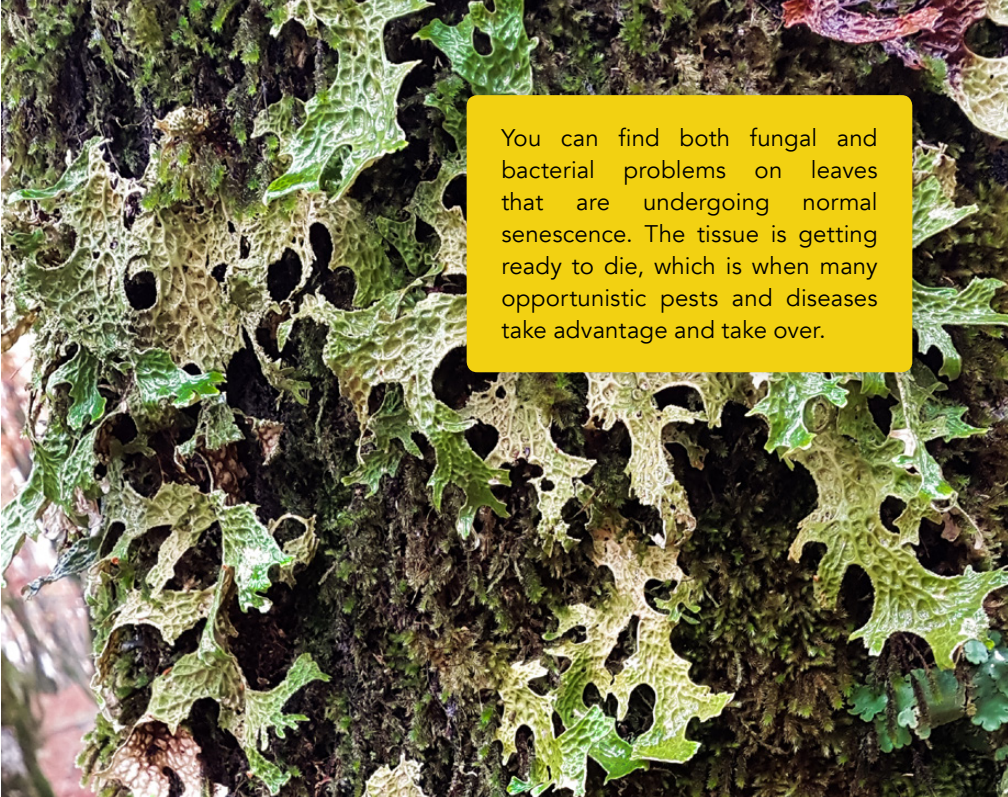
☼ Next, consider the location of the discoloration. When tips and margins become necrotic, that's a water-related stress. Surface damage is often sun related; often, the plant has been pruned improperly, and underlying leaves have been exposed to the sun, so those spots fry. If the damage is uniform, it's often nutrient related.

☼ Another thing to examine is leaf size. If a plant's leaves are smaller than normal—and you can tell because last year's leaves were bigger or other plants nearby have bigger leaves—that tells you that there is a water-related stress.

- ✿ Also consider leaf senescence out of season, or early senescence. In other words, it's summer and leaves are dying. When you see early senescence, that's telling you that the tree or the shrub isn't getting enough water. This is common in overplanted landscapes as well as with plants that aren't properly managed in terms of additional water being added during the summer if it's dry. When a plant doesn't get enough water, it gets rid of its leaves—it can always grow new ones. Because all new growth comes from its woody tissues, the plant focuses on retaining water there.

LIVING STRESS FACTORS

- ✿ Another category of stress factors is living factors, which include insects, diseases, and viruses. This is what people always think that the problem is.
- ✿ One of the things that you'll see with insect or herbivore damage is tissues that are missing or otherwise damaged in a way that doesn't look like a nonliving factor.
- ✿ In addition to missing or damaged tissues, look for discoloration—in terms of a pattern, rather than an overall discoloration, like you see with chlorosis and leaf reddening.
 - ✿ If you see a bullseye pattern radiating out from the center of a leaf, which often is either black or is actually a hole, that is where the fungal spore landed and started growing, and then it spread outward.
 - ✿ Bacterial infections on leaves tend to have angular boundaries; they don't cross the veins like fungal pathogens do.
 - ✿ If a leaf has a chlorotic pattern that doesn't look overall like interveinal chlorosis but looks almost like a web or a pathway, that is an often indicator of a viral infection.



You can find both fungal and bacterial problems on leaves that are undergoing normal senescence. The tissue is getting ready to die, which is when many opportunistic pests and diseases take advantage and take over.

IMPROPER MANAGEMENT OF GARDENS AND LANDSCAPES

- ❁ Improper management in gardens and landscapes of trees and shrubs manifests as a variety of symptoms, including the following:
 - ❁ poor planning location, which can cause opportunistic damage down the road
 - ❁ poor plant selection, which can lead to health problems in plants
 - ❁ bad soil management, including being improperly amended; being compacted, which presses the oxygen out of the soil and often leads to drought symptoms in plants; and having no mulch, which increases the likelihood of compaction and decreases water content

- ✿ lack of root establishment, which could be a result of bad roots or planting the tree or shrub too deeply
- ✿ bad staking or neglected staking
- ✿ overuse and misuse of fertilizers, especially phosphate-containing ones; organic material, too much of which leads to an overabundance of nutrients; and pesticides, which might kill beneficial microbes but also might have an impact on the plants themselves
- ✿ bad pruning, which can lead to hydras and all kinds of weird resulting growth, and overpruning, which can stress your plant and open it up to diseases and pests

READING

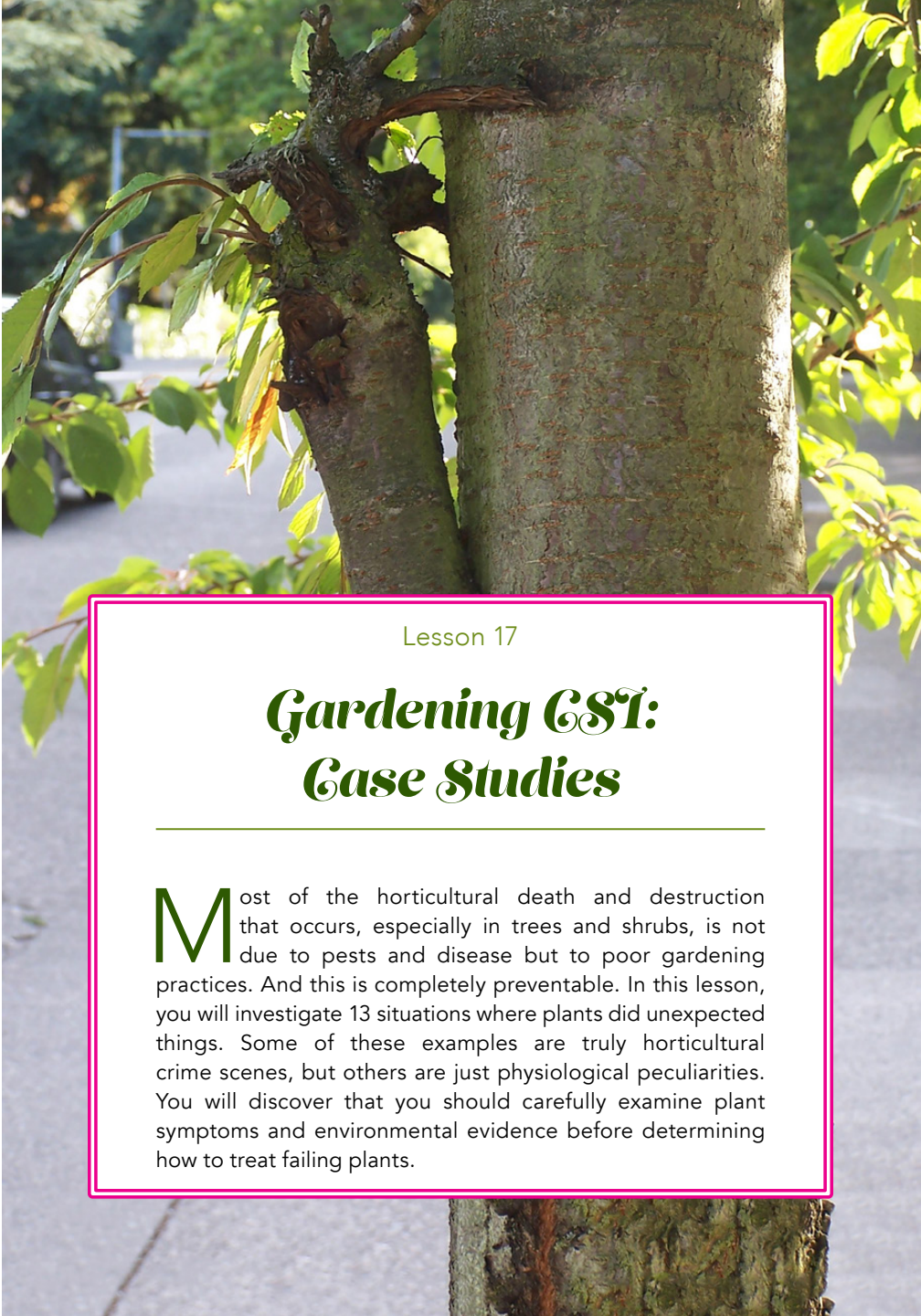
Chalker-Scott, *How Plants Work*, ch. 5.

———, ed., *Sustainable Landscapes and Gardens*, ch. 17 (contributors: Antonelli, Foss, and Glass).

———, *Why Do Leaves Turn Red?*

QUESTIONS

- ✎ It's well documented that most cases of tree death in urban areas are due to human error. Yet most people immediately assume that pests or diseases are the culprits, often because they can see insect or disease damage on their trees. Why is there such a disconnect?
- ✎ There are many web pages with diagnostic photographs of leaf damage attributed to nutrient deficiencies. Are these pages useful for home gardens and landscapes? Why or why not?



Lesson 17

Gardening CSI: Case Studies

Most of the horticultural death and destruction that occurs, especially in trees and shrubs, is not due to pests and disease but to poor gardening practices. And this is completely preventable. In this lesson, you will investigate 13 situations where plants did unexpected things. Some of these examples are truly horticultural crime scenes, but others are just physiological peculiarities. You will discover that you should carefully examine plant symptoms and environmental evidence before determining how to treat failing plants.

UNMANAGED ROOTSTOCK

- ✿ In the *Case of the Concealed Cherry*, one tree apparently disappeared and was replaced by another. In this case, shoots from the rootstock of a grafted weeping cherry tree overtook and eventually killed the less competitive weeping scion.

BAD STAKING

- ✿ Wild water sprouts pop up on trees as visual SOS signals; they are often a sign of stress. In the *Case of the Wild Water Sprouts*, a badly staked tree responded by growing new branches on the unaffected limbs. Specifically, staking material was left on a tree that girdled and killed the upper part of the crown, resulting in most of the resources going to the lower limbs, which grew water sprouts.

EFFECT OF WIND ON SHELTERED AND UNSHELTERED TREES

- ✿ In the *Case of the Tiny Trees*, unfettered trees grew to different heights compared to their neighbors. The trees on the left side of a low house were shorter while the trees on the right side were taller as a result of a directional wind coming from the left side. The wind hit the trees on the left first, so they stayed short and stocky. The trees to the right didn't get that wind and grew taller.

DIEBACK FROM CHRONIC DROUGHT

- ✿ The *Case of the Shrinking Snowberries* offers another reason why plants might get smaller over time: severe drought. One of the symptoms of chronic drought stress is dieback from the top of the plant. In this case, the snowberries didn't have enough water to support upper growth. Every year in the spring, there would be enough water and the leaves would come out, and then it would become very hot and dry and the leaves would die back. So, every year the plants got shorter until they virtually melted away.

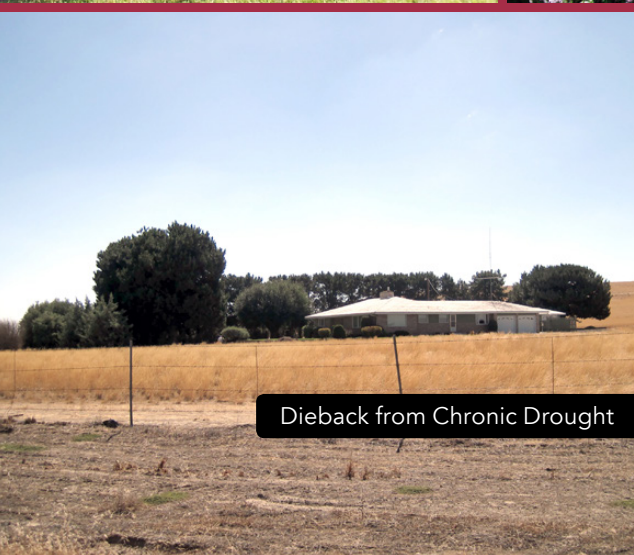
Lack of water is one of the most common reasons that plants might not reach their full potential.



Unmanaged Rootstock



Bad Staking



Dieback from Chronic Drought



Effect of Wind
on Sheltered and
Unsheltered Trees

POOR SOIL MANAGEMENT

- ✿ In the *Case of the Perishing Poplars*, poplar trees had their root systems smothered by soil that was added on top and then compacted. Roots need oxygen, and there was virtually no oxygen left once the soil was added and then compacted. The trees responded by dwarfing themselves, resorting to a smaller crown because the root system was so poor that it couldn't support the taller original crown.

PERCHED WATER TABLE

- ✿ Sometimes it's what happens below the ground and the roots that causes trees to fail, as the *Case of the Declining Dogwood* reveals. In this case, the dogwood started growing smaller and smaller leaves compared to what it previously had. The leaves weren't getting enough water because the woody roots rotted. And the reason the roots rotted was because the water table rose, so the roots were surrounded by too much water.

NO ROOT ESTABLISHMENT

- ✿ The *Case of the Receding Rhododendron* shows that pot-bound roots can signal their distress through leaf performance. In this case, a rhododendron looked healthy initially, but because of how it was planted, it eventually sprouted smaller new leaves and became unhealthy. It was planted with container media, burlap, and clay, which were all barriers to the roots getting to the native soil. The roots didn't get established and the plant exhibited signs of drought stress, such as necrosis on the tips and margins.

DAMAGE FROM UNSEASONAL HEAT OR COLD

- ✿ Leaves can remind us about weather conditions from previous weeks or even previous years, as the *Case of the Frizzled Foliage* reveals. When leaves are opening, they are the most sensitive to stress. When leaves expand, they don't have a protective cuticle; instead, they are full of water. If they're expanding and temperatures suddenly decrease or increase, they lose a lot of water and become necrotic. In this case, when the flower buds of a rhododendron were opening, there was unseasonably cold weather, and the buds turned brown.



Poor Soil Management



Perched Water Table



No Root
Establishment



Damage from Unseasonal
Heat or Cold

IMPROPER REMOVAL OF OUTER LEAVES

- ✿ Leaf damage for hot or cold conditions can happen when we prune at the wrong time of year. In the *Case of the Scorched Shrubs*, a boxwood hedge's tops were sheared, which resulted in a loss of the protective outer leaves, which were adapted to the environment's temperature. The inner leaves, which used to be protected and shaded, were then exposed, leading to leaves that were fried and bleached.

TOO CLOSE TO TIKI TORCH

- ✿ In the *Case of the Parched Palm*, the foliage was blackened and necrotic. Because entire fronds were blackened, as opposed to just the margins and tips being blackened, this was not from drought stress. It turned out that the palm was too close to a tiki torch, whose flame would blow back and forth depending on the wind. The palm suffered from that intense, localized heat exposure.

EARLY SENESCENCE DUE TO DROUGHT

- ✿ In the *Case of the Flaming Foliage*, some poplar trees turned red while others were still green, and it wasn't time to change colors yet. The red trees went senescent early, probably because they weren't being irrigated, which is called drought-induced senescence. This is usually because those particular trees are less competitive than the others for some reason. They can't get water, so rather than dying, they shut down their big water sink—the leaves—go dormant early, and then hopefully the next year they will get enough water to do better.

ARTIFICIAL LIGHT SOURCE

- ✿ In the *Case of the Persistent Poplar*, parts of trees ignored environmental cues to drop their leaves. In an urban area, a group of trees had yellow leaves, except for one area that had perfectly green leaves. This is odd because plants that are close to each other tend to change color at the same time. The trees are close to a building that has an emergency light above its door that is on 24 hours a day. The trees farthest away from this light source weren't affected, but the trees closer to the intense light were incorrectly receiving a cue that there was plenty of light, which must have meant that it was summer, so they did not go dormant.



Improper Removal of
Outer Leaves



Too Close to Tiki Torch



Early Senescence Due to Drought



Artificial Light Source



Genetic Reversion



GENETIC REVERSION

- ✿ In the *Case of the Mosaic Maple*, a variegated maple tree—which is a genetic variant of the maple that has variegated leaves—was mostly variegated but had some branches with plain bright-green leaves. If you bought this tree because you liked the variegated maple, you should have clipped out those green branches immediately. The variegated maple wouldn't exist in nature because it would be competed out, but we clone it and grow it ornamentally. We have to keep it from reverting back to its original form by clipping those green branches or the whole tree will become green eventually.

READING

Chalker-Scott, *How Plants Work*, ch. 5.

———, ed., *Sustainable Landscapes and Gardens*, ch. 17 (contributors: Antonelli, Foss, and Glass).

———, *The Informed Gardener Blooms Again*, “The Myth of Wilting Leaves.”

———, *Why Do Leaves Turn Red?*

QUESTIONS

- ✎ Look around your landscape, paying special attention to dead or dying plants. Examine areas for evidence of possible horticultural crimes. Do you know what went wrong? Keep in mind that most of the time, human error is to blame.
- ✎ Take a walk around your neighborhood to find some evidence of landscape failures. Can you assess why the plants are dying? If not, what additional information would you need?



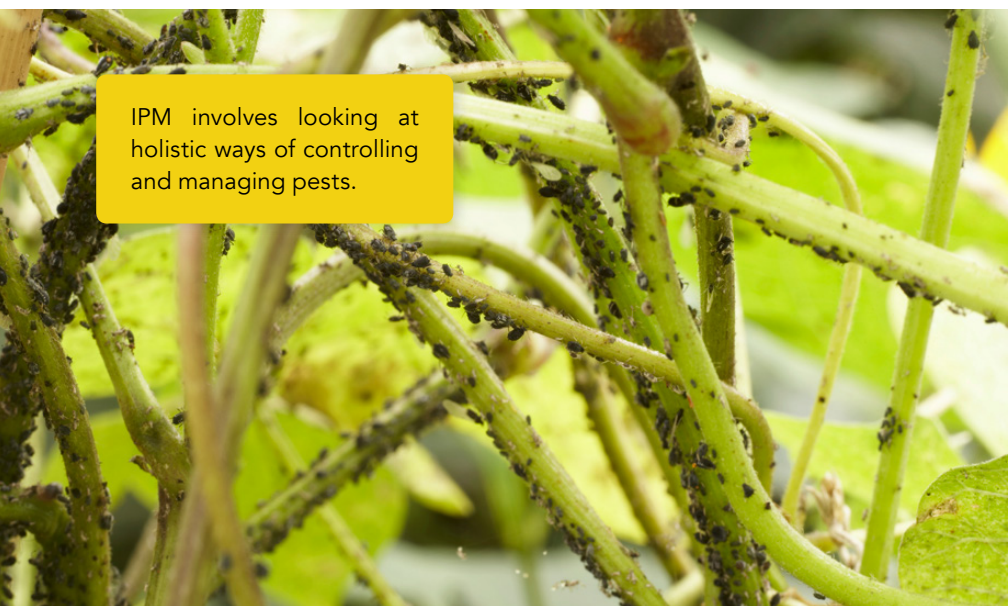
Lesson 18

Integrated Pest Management

In this lesson, you will discover how to deal with pests in the garden by managing them, not controlling them. A garden pest is anything that you don't want in your landscape. There are scads of chemical methods for controlling pests, but this lesson will focus on reducing or eliminating the use of chemical pesticides through integrated pest management (IPM), which is a systematic, science-based approach to managing your worst pest problems with a minimum of chemical inputs. Using the IPM approach, you will discover the least-toxic ways to control pests but leave your desirable garden inhabitants relatively unscathed.

HOW IPM WORKS

- ❁ When considering IPM, it's important to make sure that you've diagnosed the problem accurately. Is it an abiotic cause, such as the environment or bad planting practices? Or is it a biotic cause, such as a pest? Is it a primary pest or an opportunistic pest? Pests are often opportunistic and result from poor plant selection or management.
- ❁ You also need to know exactly what your pest is. A pest is simply an unwanted plant, insect, or other organism that may be desirable in one part of your landscape but not in another. Identifying the pest of concern is important. Fortunately, there are great internet resources, extension offices, and other ways to make sure that you identify your pest correctly.
- ❁ Next, learn its behavior and life cycle in your region. This is important for the timing of the control. You need to know when eggs hatch, if it's an insect that has a larval stage and goes through various changes and then becomes a problem; if it's a problem when it's a larva, you need to know that to figure out your control options.
- ❁ Then, monitor the pest once you've discovered it. Keep a diary. This allows you to know for your region and your particular microclimate when a pest appears and when it starts causing damage. You can also use monitoring traps to capture pests as they invade your landscape.



IPM involves looking at holistic ways of controlling and managing pests.

PRACTICING IPM

- ✿ IPM is a set of principles that uses science-based information to determine actions. It's selective for a target pest; it's not a broad-spectrum approach. It does not involve eliminating pests but makes pests manageable. The exception is for introduced pests—pests that are becoming a nuisance in your area. You want to wipe those out because you want to keep them from getting established.
- ✿ This requires the homeowner to decide how much damage you are willing to tolerate. Do you mind having a few holes in your leaves? Do you mind having a little bit of powdery mildew? If you're a gardener, it's about aesthetics. But if you're a farmer, you have to consider economic loss. Gardeners can accept more messiness in their landscapes and not expect everything to be perfect.
- ✿ Ideally, the balanced approach of IPM will reduce the quantity and frequency of pesticide use, which will make your landscape more self-correcting over time.

CULTURAL CONTROL

- ✿ The first part of the IPM approach is cultural control: Either change the plant or change the environment.
- ✿ You can try to make the plant itself less hospitable to the pest.
 - ⊗ Protect sensitive species of plants by putting up a barrier that pests can't get through, such as covering the fruit or entire plant with mesh, using protective sleeves, and using specialized fencing.
 - ⊗ Remove sensitive species and replace them with resistant ones.
 - ⊗ Use proper techniques for planting to optimize both establishment and health of the plants. Opportunistic pests often take advantage of the weakened condition of trees that are failing for reasons other than being the wrong cultivar or being pest magnets.
 - ⊗ To avoid such situations, be sure that environmental conditions are optimal for plants. For example, make sure that they have adequate water.
 - ⊗ If the environmental conditions can't be improved, replace the plants with more appropriate choices.

A man with grey hair and a beard, wearing an orange long-sleeved shirt and dark jeans, is crouching in a greenhouse. He is holding a wooden-handled tool, possibly a trowel, and is looking towards the camera. He is surrounded by tomato plants with green and red tomatoes hanging from the vines. The greenhouse has wooden frames and glass panels.

Sustainable gardeners have to tolerate some insect damage to their plants.

- ✿ There are also ways to make the environment less hospitable.
 - ⊗ Use coarse organic mulch to reduce weeds and enhance the populations of beneficial microbes and insects.
 - ⊗ Practice crop rotation and polyculture in vegetable beds or incorporate edibles into the landscape. This decreases the chances of widespread pest or disease occurrence.
 - ⊗ Prune trees and shrubs to increase their air circulation and decrease some disease problems.

MECHANICAL CONTROL

- ✿ In addition to cultural control, you can use mechanical control to physically remove the pest.
 - ⊗ Pull out weeds.
 - ⊗ Use blasts of water to remove a lot of insects; this is probably the easiest way to get rid of some types of soft-bodied insects, such as aphids.
 - ⊗ Use monitoring traps, which are often used to see how pests are progressing through a landscape but can also be used as traps.
 - ⊗ Prune out infested limbs and rough out infested plants.
 - ⊗ Don't use bug zappers and other types of broad-spectrum tools. They indiscriminately kill good as well as bad insects.



The use of woody mulches will reduce your weeding chores.

BIOLOGICAL CONTROL

- ✿ Biological control involves introducing a predator, parasite, or parasitoid (which kills its prey by laying an egg inside the prey and eventually eats it from the inside out) to an introduced pest population. Introduced pest species will have natural enemies in their original environment, and these enemies can be used to control the pest in the new environment.
- ✿ Researchers study the efficacy of biocontrol agents in quarantined conditions and determine the relative risk of introducing yet another foreign species. Then, the industry makes biocontrol agents commercially available to people in agriculture as well as to home gardeners.
- ✿ One way to use biological control is by classic introduction. An example of this involves controlling tansy ragwort, which is a toxic weed that cattle eat and die from, in the United States. In its natural habitat in Europe, an insect called the cinnabar moth is a natural predator of tansy ragwort. Once researchers discovered that the moth didn't really affect other species, they brought them over to keep the tansy population in check.
- ✿ A second way of using biological control is by disrupting mating. The easy way to do this is by using sex hormones, or pheromones, that insects can pick up. Generally, the male picks up a scent from females, and you can disrupt mating by introducing it at the wrong time of year or by setting up traps so that the males get trapped and therefore can't find females. This method has been very successful with codling moths, which is a pest on apples.
- ✿ A third way is by augmenting natural enemies. This is something that you can do without having to figure out if it's going to be a problem for other plants, because these are enemies that are already around—they're not new introductions. This method includes using lacewings for aphid control, or certain nematodes for controlling root weevils, or even parasitic wasps, which attack all kinds of pest insects.



cinnabar moth



tansy ragwort



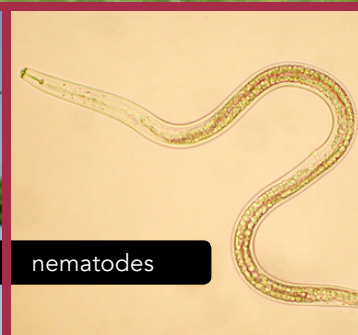
codling moths



parasitic wasps



lacewings



nematodes



Lady beetles are a wonderful predator on aphids and other pests—but do not buy them. Many purchased lady beetles aren't natives, and they can physically displace the native species of lady beetles. In addition, the collection of lady beetles degrades the native environment. Instead, make your landscape more hospitable to lady beetles: If you build it, they will come.

- ✿ A fourth method of biological control is the use of natural pathogens. An example is *Bacillus thuringiensis* (*Bt*), which is a natural pesticide that can be used against a number of insect pests. For example, there are specific natural variants for the Colorado potato beetle, for the gypsy moth, and for mosquitoes
- ✿ A final method involves analyzing the competition for space on roots and leaves of plants. Allow natural probiotics to thrive by reducing your use of fungicides and bactericides. Also, use woody mulch to provide spores of beneficial bacteria and fungi.

CHEMICAL CONTROL

- ✿ Chemical control is the last resort.
- ✿ Chemical control is very important when you're looking at new pests and diseases, such as emerald ash borer (which affects ash trees) and thousand cankers disease (which affects walnuts). These need to be managed as quickly as possible, and many times that is done by using pesticides to drive the population down before it explodes in other regions.
- ✿ Chemical control can help eliminate persistent pests from specific areas. An example is Canadian thistle, which is a thorny weed that is difficult to manage. You can cut it and apply a targeted herbicide on the cut surfaces to kill it.

CONSEQUENCES OF IMPROPER PESTICIDE USE

- ✿ There are many consequences of improper (broad-spectrum) pesticide use.
 - ✿ Broad-spectrum pesticides can cause pest resurgence because they kill pests as well as beneficial species. Keep in mind that when you kill a beneficial, you inherit its work.
 - ✿ Broad-spectrum pesticides can cause secondary pest outbreaks by killing a beneficial predator or parasite of another pest.
 - ✿ Broad-spectrum pesticides can cause pest resistance by using the same product repeatedly.

BEST PRACTICES FOR PESTICIDE USE

- ✿ There are some best practices for pesticide use to consider if you have to use pesticides.
 - ✿ Determine that pesticide use is critical for plant survival, not just for your aesthetic desires.
 - ✿ Choose the most specific pesticide possible. It needs to be a legal, registered pesticide for use by homeowners.
 - ✿ Choose the least toxic pesticide possible. For example, try a repellent first rather than something that will kill the insect.

- ☼ Choose premixed products. This is easier than mixing your own and is guaranteed to be accurately done. Stronger doesn't necessarily mean that it will work better.
- ☼ Read labels carefully (especially to see if the product needs to be diluted).
- ☼ Spot spray only where needed.
- ☼ Ensure that bees and other pollinators will not be affected. Consider the timing of using pesticides; make sure that you're not using them during flowering time.
- ☼ Never use home remedies in the place of tested pesticides.

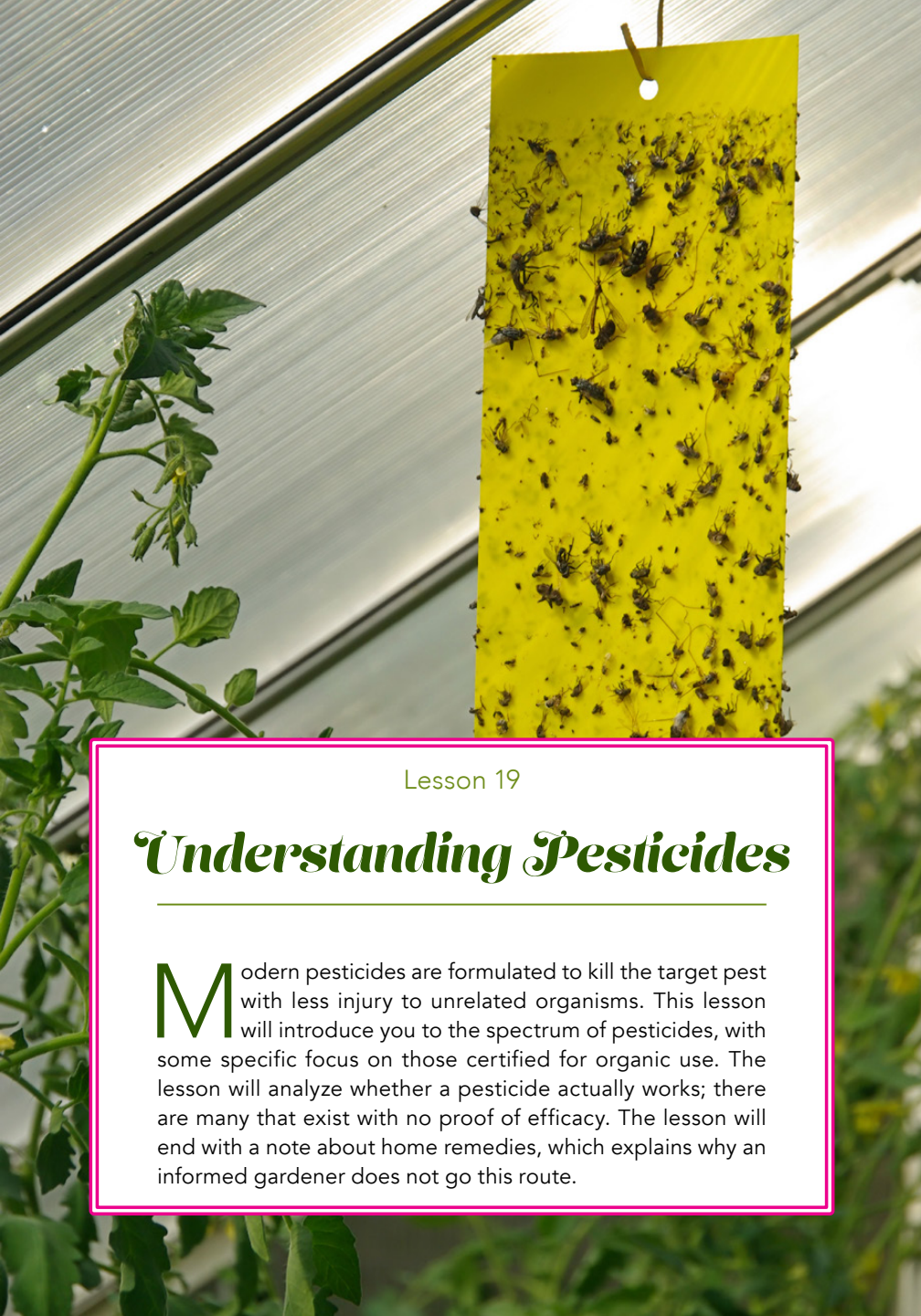
READING

Chalker-Scott, *The Informed Gardener*, "The Myth of Organic Superiority," parts 1–2.

Chalker-Scott and Bush, *Should We Buy Lady Beetles for Our Gardens?*

QUESTIONS

- ☼ Why is it important to know whether an insect or disease is a primary stressor or an opportunistic problem?
- ☼ Sometimes a fifth prong is added to the IPM approach: regulatory control. This means that policies are made at the state or national level regarding invasive species, including plants, insects, and diseases. Should this be part of the IPM approach? Why or why not?

A yellow rectangular sticky trap is hanging vertically, covered with numerous small, dark-colored insects, likely aphids. It is positioned in front of a translucent greenhouse panel. To the left, a green tomato plant with leaves and small developing fruits is visible.

Lesson 19

Understanding Pesticides

Modern pesticides are formulated to kill the target pest with less injury to unrelated organisms. This lesson will introduce you to the spectrum of pesticides, with some specific focus on those certified for organic use. The lesson will analyze whether a pesticide actually works; there are many that exist with no proof of efficacy. The lesson will end with a note about home remedies, which explains why an informed gardener does not go this route.

PESTICIDE BIG PICTURE ISSUES

- ✿ You can only use a pesticide for what it's labeled to use on. This is why it is important to read the label.
- ✿ Legal pesticides are registered both by the EPA and by your state department of agriculture. It's important to check if a particular pesticide is legal to use in your state.
- ✿ Before a pesticide is registered, published, peer-reviewed research must show the impacts on human health and the impact on environmental safety.
- ✿ The EPA does not require any evidence of product efficacy. There's no regulatory arm in the EPA for this. Efficacy information is supposed to be provided by the company that is marketing the product, which could misrepresent the efficacy of the product.
- ✿ Success in lab testing of many of these products does not guarantee success in the field. And overextrapolation is a common problem with many garden-related products, including some pesticides.
- ✿ Keep in mind that using a pesticide should be the last resort.

PESTICIDE TYPES

- ✿ A pesticide is defined as any substance that is intended for preventing, destroying, repelling, or mitigating any pest.
- ✿ The term "pesticide" is the umbrella term under which exist insecticides, which kill insects; miticides, which kill mites; and nematicides, which kill nematodes. Then there are bactericides and fungicides, which will kill bacteria and fungi, respectively, which really shouldn't be used because they are harmful to living landscape soils. Then there are herbicides, which kill plants; molluscides, which kill slugs and snails; and rodenticides, which kill rodents.
- ✿ Pesticides are either selective or nonselective. A selective pesticide is targeted toward a particular pest's reproduction. A nonselective pesticide will kill not only the target organism, but also all related organisms, whether the organism is good or bad.

- Pesticides can also be divided up as organic or synthetic. An organic pesticide is natural, while a synthetic pesticide is manufactured, often based on a natural pesticide. Some synthetics are more targeted than their organic components.

Pyrethrin is a natural insecticide that chrysanthemums make. A synthetic version, called pyrethroid, is more targeted and less toxic to nontarget organisms.



- The perception that many people have is that natural, or organic, chemicals are safer than synthetics or other types of more conventional pesticides. But this isn't true. Many synthetic pesticides are safer versions of a natural pesticide. Organic and natural does not equal safe.
- Our focus is primarily on products that are certified by the Organic Materials Review Institute (OMRI), because many gardeners are interested in organic gardening approaches. The OMRI list of certified products will tell you what is approved for organic gardening. But just because OMRI approves usage does not mean that your state approves it. States will vary in whether or not products are legal for home use; state departments of agriculture lists should be consulted.

A photograph of a field of tobacco plants. The plants are lush green with large, broad leaves. The field is densely packed with these plants, and the ground between them is visible as dark soil.

Nicotine is a highly toxic but natural insecticide. Neonicotinoids are a synthetic version of nicotine that have been tweaked so that they are not nearly as toxic to nontarget organisms.

- ✿ We won't be considering many conventional pesticides because their formulation and usage is tightly controlled. We're venturing into the Wild West of pest control. Many pesticides fall into the GRAS (generally regarded as safe) area. Their use is not tightly regulated.

MODES OF ACTION OF PESTICIDES

- ✿ To use a preventative pesticide, you must be able to predict pest behavior, such as life cycle timing.
 - ⊗ One way to prevent pest damage is to interfere with feeding. First, you can use something that smells bad, which can be a repellent or something that induces fear. Second, you can use something that tastes bad, which can be an irritant or a repellent. Third, you can use something that affects how a material feels, such as giving it an oily or gritty texture.
 - ⊗ Another way to prevent pest damage is by interfering with egg laying. One way to do this is to make a surface inaccessible to the pest that is trying to lay eggs there. You can also make the surface unpleasant, such as by adding oil to it.
 - ⊗ This will also work for spore and seed germination. You can make the surface inaccessible, such as by covering it, or you can change the surface's chemistry, such as its pH. These methods will prevent the organism from reproducing.
- ✿ Instead of preventing pest damage, you can cure the problem, which involves dealing with the pest once it's already present.
 - ⊗ One way is by suffocation, by covering the surfaces or clogging the pores.
 - ⊗ A second way is by starvation, by using chemicals that poison the digestive system.
 - ⊗ Third, you can disrupt biochemical or physiological processes, by using methods such as roughing up the waxy cuticle of insects or weeds, interfering with the pest's ability to grow and develop, poisoning the pest's enzymes, and using neurotoxins to kill the pest.

PESTICIDE GROUPS

- ✿ Pesticides can be grouped into inorganic chemicals, organic chemicals, botanical derivatives, biocontrol organisms, and biological products.
- ✿ There are several inorganic chemicals that you might be able to use.
 - ⊗ Boric acid can be used as an insecticide.
 - ⊗ Various forms of copper can be used. Copper sulfate is a fungicide, an algaecide, and a moss killer.
 - ⊗ Diatomaceous earth, which is basically ground-up diatoms—whose exoskeleton is glass-based— help abrade insects' cuticle, causing them to dry out.
 - ⊗ Ferric phosphate is effective on slugs.
 - ⊗ Kaolin, which is kind of a clay, is effective on insects. It often gets recommended for slugs, but it is not labeled for slug use and should not be used to kill slugs.
 - ⊗ Potassium bicarbonate is registered for pesticide use as a fungicide. Potassium bicarbonate is not sodium bicarbonate, although they work in similar ways. Sodium bicarbonate is a home remedy that puts sodium, or salt, into the soil, so it is not recommended.
 - ⊗ Sulfur can be used as a fungicide or as a miticide.
- ✿ In contrast, there are organic chemicals. (These are organic in the chemical, not functional, sense.)
 - ⊗ Oils don't have a biological activity; they have a physical activity. Sesame oil and other registered, mostly vegetable, oils can be used, but petroleum-based oils can also be used.
 - ⊗ A variety of organic soaps, such as sodium lauryl sulfate, can be used.
 - ⊗ Vitamin D₃, or cholecalciferol, can be used as a rodenticide.

- ✿ Another way to group pesticides is by ones that are derived from botanical materials.
 - ⊗ Extracts are remarkable in terms of their activity and sometimes their targeting. The one that gardeners are most familiar with is neem, whose active ingredient is azadirachtin. Neem oil is used very effectively as an insecticide. Pyrethrin, which comes from chrysanthemums, is an insecticide. Pyrethroid, a synthetic version, is not recognized for organic gardening use.
 - ⊗ Physical oils, such as castor oil and sesame oil, don't have a chemical activity, but they do offer a physical barrier of keeping insects or fungi off of leaves and causing damage.
 - ⊗ Essential oils are primarily repellants. A number of essential oil products are listed by the OMRI, including black pepper, cedar, cinnamon, clove, garlic, peppermint, rosemary, thyme, and wintergreen. These have been tested not necessarily for efficacy, but in terms of being certified as organic and not having an effect on ecosystems or human health.
 - ⊗ The problem with these particular products is that the usage has been overextrapolated. Many aromatic oils that humans like the smell of are repellant to a variety of insects. But they're volatile, so they are short-lived in the landscape. They work best in enclosed areas, such as beehives and greenhouses. But essential oils are generally not cost-effective.
 - ⊗ Some essential oils can be phytotoxic. In other words, if you apply them directly to plants, they will have a negative effect on the plant. Phytotoxicity can be species-specific, and it can occur if you apply too much of an essential oil or if the temperature is too high. Before you use essential oils on any plant, test it on a specific location of the plant.
 - ⊗ Mixed essential oil products are popular. The problem with these products is that they haven't been tested as single oils have. Research has found that blending extracts does not ensure enhanced biological activity and that numerous plant-derived essential oil products have not been subjected to rigorous evaluation. In addition, research has found that these products vary in their effectiveness against certain arthropod pests (insects) and are phytotoxic.

- ❁ Biocontrol organisms have gone through rigorous scientific testing for environmental harm and for human health effects. There are several groups of organisms that can be used in the home garden.
- ❁ Bacteria is one of the most exciting developments in this category. *Bacillus thuringiensis* (Bt) and related *Bacillus* species can be used as insecticides. *Paenibacillus popilliae* is a milky spore insecticide. *Pseudomonas* species work on fire blight bacteria. *Streptomyces* species are effective against certain fungal pathogens, such as *Fusarium*, *Septoria*, and *Pythium*.
- ❁ A variety of fungal species also have biocontrol activity. Most of the fungi in this group are usually found in the soil and can cause natural outbreaks on their own when environmental conditions are favorable. *Beauveria bassiana* is a broad-spectrum insecticide; *Coniothyrium minitans* works on fungal disease organisms, such as *Sclerotinia*; *Gliocladium virens* attacks damping off and other root pathogens; *Nosema locustae* affects grasshoppers but also other nontarget organisms, such as bees; and *Trichoderma harzianum* attacks fungal disease organisms, such as *Rhizoctonia* and *Sclerotinia*.
- ❁ Nematodes, such as members of the *Steinernema* species, are effective insecticides.
- ❁ Virus sprays can be used to attack particular pests, such as the codling moth, which is susceptible to the granulosis virus.



codling moth

- ✿ There are also biological products.
 - ⊗ There are microbial (bacterial) products, such as Spinosad, which is a fermentation product from bacterium *Saccharopolyspora spinosa*. It's a broad-spectrum insecticide.
 - ⊗ There are plant-derived products, such as corn gluten meal, which is an herbicide under certain circumstances.
 - ⊗ There are also animal products. The problem with these products is that there is rapid habituation when feeding pressure is high.
 - There are four ways that these products can have an effect: neophobia (it's new, so the animal doesn't like it); conditioned aversion (the animal avoids a certain food after becoming sick after eating that food); irritation (the animal's mucus membranes swell up after eating a certain food); flavor modification (something is added to a plant that makes it taste horrible—for example, soapy or bitter—so the animal stops eating it).
 - The types of products that you can find on the shelf that fall into these categories include dried blood, which is a flavor modifier; bone meal, which has a neophobic effect; capsaicin, which is an irritant; urines from natural predators, such as coyotes and foxes, which have a neophobic effect (urine from nonpredators is ineffective); putrescent egg solids, which are smelly; pheromones, which can be used to repel various types of animals; and thiram, which is a chemical that causes gastric upset and is an example of conditioned aversion.

DRAWBACKS OF ORGANIC PESTICIDES

- ✿ There are some drawbacks of using organic gardening pesticides.
 - ⊗ Broad-spectrum pesticides can kill beneficial species and other nontarget organisms.
 - ⊗ More frequent application is often needed.
 - ⊗ Pests can develop resistance.
 - ⊗ Some products are phytotoxic.

HOME REMEDIES

- ❁ Home remedies are not recommended. They haven't been tested for efficacy, and they often use broad-spectrum materials in terms of what they'll kill. Examples include dish soap, Epsom salts, vinegar, boric acid mixed with peanut butter, mothballs, and tobacco sprays.



Although many popular books and websites recommend home remedies, they are rarely effective and in fact can cause great damage to desirable plants and insects.

- ❁ Home remedies are not formulated for pesticidal use and shouldn't be used. They often have broad and significant toxicity. They are not tested for human health or environmental safety by the EPA. They are not legal to recommend as pesticides, and you should not apply them to your own gardens.

READING

Chalker-Scott, *The Informed Gardener*, "The Myth of Compost Tea."

———, *The Informed Gardener*, "The Myth of Compost Tea Revisited."

———, *The Informed Gardener*, "The Myth of Organic Superiority," parts 1–2.

———, *The Informed Gardener Blooms Again*, "The Myth of Bubbly Compost Tea."

QUESTIONS

- ❁ Should efficacy testing be part of the process for pesticide registration? If so, who would do the testing, and how would such testing be funded?
- ❁ Essential oils can be effective insecticides in closed spaces, but not in the garden or landscape. Can you think of ways to increase the efficacy of essential oils used outdoors?



Lesson 20

What to Do about Weeds

A weed is simply a plant that is out of place. In this lesson, you will learn about where some weeds came from and why they ended up in the United States. You will discover some of the worst perennial weeds that can be found in your region, consider the damage they cause—not just to your garden, but to other areas they can easily invade—and use the IPM approach (cultural, mechanical, biological, and chemical control mechanisms) to create a multipronged control strategy. The last resort, chemical control, is only considered for truly problematic weeds.

DEFINING WEEDS

- ✿ Europe, Asia, and Africa tend to be the more common countries that weeds came from to the United States. There are several reasons why they were brought to America.
 - ✿ Many weeds were brought as food by immigrants.
 - ✿ Ornamentals were brought to and from various places by plant explorers throughout history. This is propagated, unfortunately, by the horticulture industry, who sometimes aren't aware of the problematic nature of many of the plants and don't understand how weedy they can become.
 - ✿ Some weeds were brought as functional plants. In other words, they were brought to control erosion or to make hedgerows or windbreaks.
 - ✿ Many weeds were brought accidentally; they were packed in ballast and packing materials as seeds.
- ✿ Noxious weeds tend to be competitive for water, space, nutrients, and sunlight; persistent; and invasive.

CONTROL OPTIONS

- ✿ There are several options for controlling noxious weeds.
 - ✿ Life history traits will affect control options. Does the weed spread seeds sexually or vegetatively? If you have to treat a weed that is going to seed, you'll want to deal with it when it's in its reproductive form. If it's a weed that spreads by roots, rhizomes, or runners, then you will be dealing with soil issues instead. Also consider the weed's toxicity to herbivores. Some ways to deal with weeds have to do with bringing in grazers, but if it's a toxic plant, then you can't use that option.
 - ✿ In terms of cultural control, mulches can reduce bare soil and light availability. Another method of cultural control is increasing landscape diversity, which can increase competition for water and nutrients with weeds and can decrease sunlight to weeds by creating a canopy shade.



- ⊗ There are also mechanical ways of dealing with weeds. To kill seedlings in hardscape areas, pour boiling water on them or use a steamer or even a flamethrower. Mowing and mulching is a particularly great way of taking care of established perennial weeds: You mow everything flat and then bring in about a foot of course woody mulch, which most of the weeds won't be able to grow up to. You can also pull weeds with your hands as soon as you see them.
- ⊗ There are also biological methods. Goats and other ruminants can be brought in temporarily to clear sites. A few types of insects have been introduced as biological control agents and are very effective with certain weeds.
- ⊗ Finally, there are chemical controls. Some certified organic herbicides, such as herbicidal oils and horticultural soaps, offer broad-spectrum physical control. There are also some biological control agents, such as *Myrothecium verrucaria*, which is a fungal species that contains a cellulose decomposer and works best on rapidly growing plants with few foliar protectants. In addition, corn gluten meal offers physical and maybe herbicidal control of weed seedlings in terms of suppressing growth, but its success might have been overextrapolated. As a by-product of corn packaging and processing, corn gluten meal works in certain climates but not in others, and at 10 percent nitrogen, it's a great fertilizer.

Glyphosate targets an enzyme that is found only in plants and some fungi. When applied correctly, it stays within the plant and moves to areas of activity. Success depends on the target and the time of year.

Controversy surrounds glyphosate regarding human health hazards. When any pesticide is registered, it has to go through strict testing by the EPA for both human health toxicity and ecosystem toxicity. Glyphosate passed those hurdles decades ago, and there is a lot of research behind it.

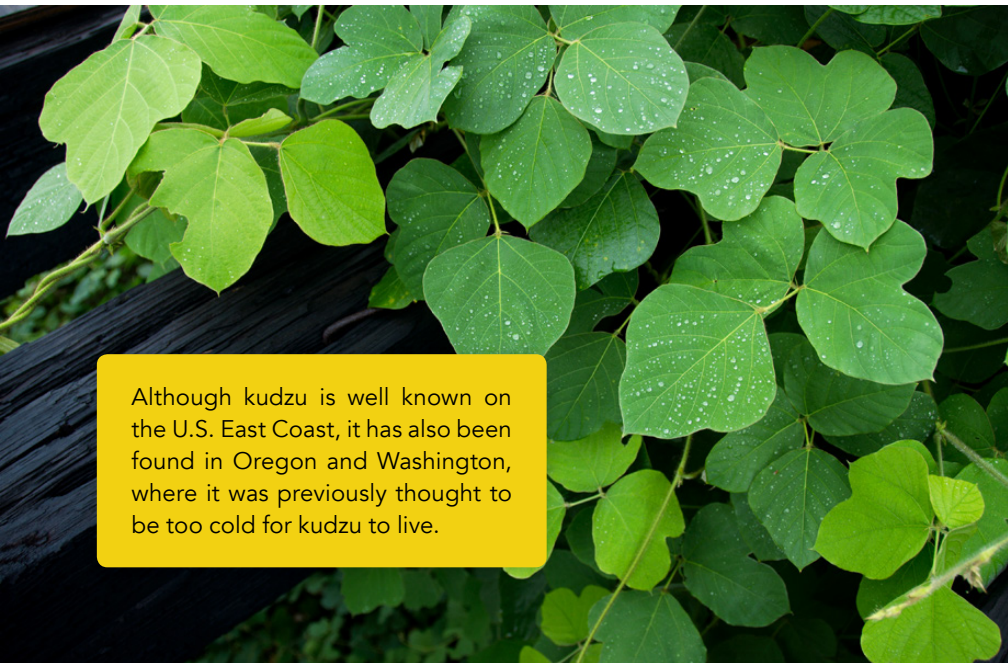
But a number of unqualified researchers have tried to make a case for getting rid of glyphosate based on the correlation of human health hazards with glyphosate usage. The problem is that correlation is not evidence of causation.

THE WORST WEEDS IN THE UNITED STATES

- ✿ Many weeds are problematic in the United States, but we will focus on ones that were deliberately introduced for particular reasons and that have had a real impact, especially on gardeners, in various parts of the country.
- ✿ English ivy (*Hedera helix*) is an ornamental vine that is native to Europe, where many immigrants came from. It has an emotional appeal to immigrants as well as to their descendants.
 - This vine does both ecological and environmental damage. It creates a monocultural ground cover, which is competitive with other low-growing plants for water, nutrients, and light. It also damages trees and shrubs as it climbs them because its weight increases the likelihood of breakage, especially in the winter. Furthermore, it provides a habitat for pests, especially rats.
 - There are a few ways that this plant spreads: It forms berries that birds eat and disperse, and the plant's vegetative parts give way to new plants.
 - There are a variety of ways to control it. First, grazers, such as goats, will eat this ivy down to the ground. Second, herbicides are variable in effectiveness. Glyphosate translocates down to the roots and kills them, but spraying glyphosate on the leaves of the ivy doesn't work because the leaves are waxy, so the material doesn't move easily across the leaf. Cutting and painting with a translocatable herbicide is the only reliable way. Third, mowing the ivy to the ground and then mulching it, letting it die back, is superior to other nonchemical methods, especially if it's timed with physiological activity. This method involves minimal soil disturbance. Mowing removes most of the resources, and mulching restricts light (and deeper mulch is better).

☼ Kudzu (*Pueraria* species) is an Asian ornamental vine that was introduced in the late 1800s. It was used during the Dust Bowl years to stop soil erosion. Unfortunately, it also got out of control.

- The ecological and environmental damage is very similar to that of English ivy, but it's probably worse because it grows much faster and is lighter and more aerial. It is damaging to the health and survival of the trees and shrubs that it covers. Like English ivy, kudzu creates a monocultural ground cover, which is a problem.
- It spreads primarily by rhizomes and runners, so it spreads both above ground and underground.
- How do we control kudzu? For grazers, it's desirable as forage; it's rich in nitrogen because it's a nitrogen fixer, so it's nutritionally sound as well as edible. The fungal species *Myrothecium verrucaria* has been used successfully on kudzu with minimal damage to underlying woody plants; treated kudzu shows damage within hours of being applied. Mowing and mulching might also be successful. Translocatable herbicides, such as glyphosate, also work well.



Although kudzu is well known on the U.S. East Coast, it has also been found in Oregon and Washington, where it was previously thought to be too cold for kudzu to live.



English ivy



Purple loosestrife



Tamarix

- ☼ Purple loosestrife (*Lythrum salicaria*) was introduced deliberately by immigrants. It's an ornamental, wetland herbaceous perennial that originally came from Europe, Asia, Africa, and Australia.
 - This plant colonizes wetlands; displaces other emergent wetland plants, such as cattails and reeds; makes dense monocultures that fish and waterfowl can't penetrate; reduces water flow; and creates a vast seedbank.
 - It spreads by seeds and root segments.
 - Biological control is highly successful. Five insect species, including leaf beetles and weevils, cause significant damage to the plant through defoliation. Small infestations can be easily pulled out. Chemical control should be avoided because aquatic damage could be significant.
- ☼ *Tamarix*, which is native to dry regions of Asia and Africa, has deciduous and evergreen species. It was deliberately introduced as an ornamental shrub, a functional windbreak, and an erosion controller during the Great Depression.
 - It competes for water and space in a wide range of water and salt conditions. It forms dense monocultural thickets. The seeds are easily spread by the wind as well as on hikers' shoes, such that it is now endangering native palm oases in the southwestern United States.
 - It spreads by seeds and underwater roots.
 - A great biological control organism is the northern tamarisk beetle, which has been used especially in the national park system to keep the shrub under control and to eventually replace it with native plants. With smaller populations, you can cut and paint it with glyphosate or another translocatable herbicide.



You can find specific control options on local invasive weeds through your state department of agriculture, which maintains a noxious weed control list. Extension offices at the state and county levels may also have practical solutions.

READING

Chalker-Scott, "Impact of Mulches on Landscape Plants and the Environment."

———, *The Informed Gardener Blooms Again*, "The Myth of Weed-killing Gluten."

———, *Using Arborist Wood Chips as a Landscape Mulch*.

Reichard, Chalker-Scott, and Buchanan, "Interactions Among Non-Native Plants and Birds."

QUESTIONS

- ✎ Many invasive weeds appeared to be well behaved early in their introduction to the United States. It wasn't until several decades later that they became nuisance species. Why would this be the case?
- ✎ Given what we know about invasive plant species listed as noxious weeds, should their sale be banned in nurseries? Should their sale be banned on the internet? How would these bans be enforced?



Lesson 21

What to Do about Insects

In this lesson, you will learn about the bugs that bug you in your garden. You will consider how the four prongs of IPM—cultural, mechanical, biological, and chemical control—can be generally applied to controlling pest insects. You will learn about some of the most widespread examples of garden pests and discover specifically how to get them under control, or at least manage them.

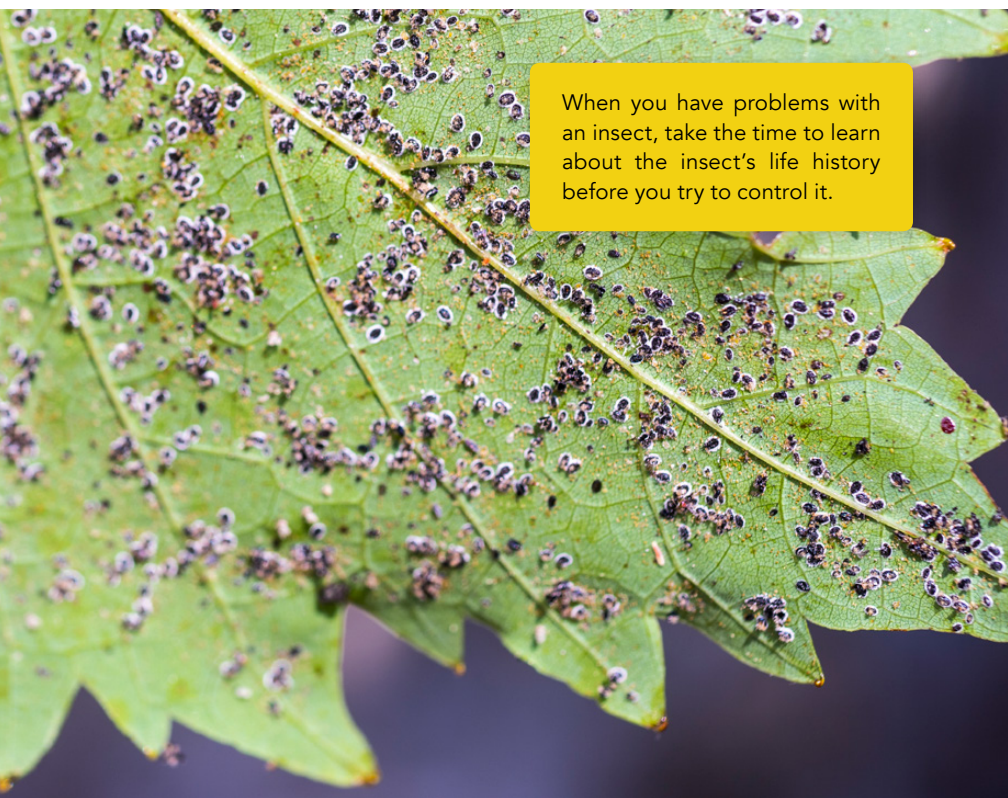
CONTROL OPTIONS

- ✿ In general, cultural control for insects involves increasing landscape diversity. This creates a habitat for predators and parasitoids, which can help control the insects that you don't want in your garden. Use polyculture or intercropping—which involves interspersing vegetable plants and ornamentals, for example, instead of having all the same plants in one area. This confuses pests, who will have to actively search for host plants.
- ✿ Another method of cultural control is the use of ground covers and coarse, woody mulches, both of which provide habitats for predators and parasitoids.
- ✿ Another method is the use of trap plants, which are specific for particular pests. This involves knowing a pest's food desires and planting its favorite food so that perhaps it won't attack the plants you intentionally planted that the pest was destroying.
- ✿ There are also mechanical ways of dealing with insect pests. Physical removal includes picking off and destroying the pest, using a hose spray, and using sticky traps.
- ✿ There are also physical repellants, such as diatomaceous earth. Made from the ground-up exoskeletons of diatoms, it can scrub the cuticle of insects to allow water to get out, causing desiccation. It can also suffocate insects by getting into the holes used for oxygen and carbon dioxide exchange. In addition, kaolin clay and oils can be applied to the leaves of plants to repel insects by altering the taste and texture of the leaves and to prevent egg laying on the leaves.
- ✿ In term of biological control, a variety of diseases have been found to be specific for many agricultural pests that just happen to also be pests in gardens. Other forms of biological control are parasitoids and nematodes, both of which eat their prey from the inside out; predators, which consume the whole insect; and pheromone traps.
- ✿ The last resort is chemical control, which includes conventional insecticides, which are often such broad-spectrum treatments that they cause more damage than they cure.



THE WORST INSECTS IN THE UNITED STATES

- The following are examples of some of the insects that, if you live in the United States, you've probably seen in your landscape and garden and want to know how to deal with.
- There are many genera of aphids, which reproduce quickly and have very few defenses.
 - For cultural control of aphids, habitat is important—not just for controlling the aphids but also for managing and nurturing their predators. First, keep weed populations down. Second, don't overfeed your plants; excessive nutrients can lead to plants with lots of vegetative growth and reduced defenses. Third, provide nectar-producing plants for wasps, which can help control aphids. Fourth, provide a water source to encourage beneficial insects to stick around. Finally, provide shade, which gives beneficial insects a place to live.



When you have problems with an insect, take the time to learn about the insect's life history before you try to control it.

- For mechanical control, use your garden hose to spray aphids off your plants. Put your thumb over the hose or use a low-intensity setting. They come off easily because they don't have good ways of attaching to plants. They fall to the ground and might not be able to get back up to the plant or might be eaten. This doesn't damage the plant; in fact, it provides water—and also costs virtually nothing.
- In terms of biological control, there are many things that like to eat aphids, because they have very few defenses, are soft, and contain lots of water and sugar. Lady beetles love aphids. But don't purchase them; instead, keep your landscape diverse so that lady beetles come naturally. Lacewings, which can be purchased, are easily grown and released and don't tend to leave the area as quickly as lady beetles do. Parasitic wasps will find aphids, lay eggs, and the larvae will kill individual aphids. There are also several fungal insecticides available that control aphids.
- Finally, there are chemical controls as a last resort. All of these chemical controls are broad spectrum, which means you will be killing anything that you are spraying on, so they're not recommended. But if you have a plant that you need to treat, you can consider using horticultural oils on the surface of plants, insecticidal soaps, pyrethrum (the natural form from chrysanthemums) as well as pyrethroid, and neem.

A close-up photograph of a person's hand holding a yellow spray nozzle, spraying a green leaf. The background is blurred, showing more green foliage and a pink flower.

Both insecticidal oils and soaps remove waxes from organisms, causing damage to insects and plants alike. Be careful when using these compounds on plants because they can be phytotoxic.

- ⊗ There are many genera of mosquitoes, which are not a problem for plants but cause gardeners problems.
- You can control mosquitoes, at least to a certain extent, by keeping grass and weeds cut down low to reduce adult habitat and by reducing standing water availability. Standing water can be found in dog bowls and old tires, for example. If you can, simply drain the water. If you need the water for some purpose, apply oil to the surface, which prevents mosquitoes from egg laying. But this is not advised for living aquatic ecosystems. For ornamental ponds, add aeration, such as a stream that runs into the pond to keep the water moving, and fish, such as goldfish.
 - There is really no way to use mechanical control for either adults or the larvae.
 - In terms of biological control, *Bacillus thuringiensis*, as well as varieties and even other species of *Bacillus*, will kill mosquito larvae. You can buy mosquito dunks, which are donut-shaped vessels that contain *Bacillus* species that you place in a body of water. Fish and other natural aquatic predators can be introduced to the body of water. If there's a disease outbreak, you can also introduce sterile males into the population to prevent fertilization.
 - Because adults fly around everywhere, there's no real chemical control for them. To keep mosquitos away from you, use repellants as skin applications. Consult the CDC's list of recommendations. The best is anything that contains DEET. If you aren't fond of DEET, consider eucalyptus oils, which seem to have some efficacy.

Managing Mosquitos: What Doesn't Work

Don't waste your money on ultrasound devices. They don't work; there is no regulation on them.

Bug zappers work because anything that touches them dies, but they will attract mostly beneficial insects, such as moths, not mosquitoes.

Citronella candles and oils can be used inside with some effectiveness, but if they are used outside, they will dissipate and are not very effective.





☞ Japanese beetles (*Popillia japonica*) are thought to have been introduced with a shipment of bulbs in the early 20th century. They cause a lot of ecological and environmental damage. They damage grasses as larvae and many host plants as adults.

- In terms of cultural control, avoid species of plants that attract adults, and plant species that don't attract adults.
- There are some mechanical ways of keeping these insects away. If you have vegetable beds that are relatively the same height, you can put floating row covers over them. You can also use kaolin clay spray as a barrier. Or you can remove them by hand: Bend down a shoot of your plant, put a plastic bag over it, and shake it to obtain a bag full of beetles that you can then destroy.
- There are many biological controls. The *Istocheta aldrichi* fly and the *Tiphia vernalis* wasp will attack adults. *Paenibacillus popilliae* causes milky spore disease, and *Heterorhabditis bacteriophora* attack turf-living larvae. In addition, pheromone traps can be used to catch these insects, but they often attract more than they catch. They are most effective when they are placed over the entire edge of your property that's upwind.
- There is limited effectiveness with chemicals, such as pyrethrum and neem, so they're not recommended.

☼ Lace bugs (*Corythucha* species) are beautiful insects, but they cause great aesthetic damage to plants, especially rhododendrons and azaleas. They feed on the undersides of leaves by piercing the epidermis and sucking the sap, leaving a silvery or bronzed bubble.

- Culturally, you can try to avoid known sensitive species of plants and choose resistant varieties. Also, give your plants lots of tender loving care—mostly in the form of water, but mulching is also important—to keep them as healthy as possible.
- There are no mechanical controls for lace bugs.
- There are several biological controls, many of which live in woody mulches, including lacewings, spiders, assassin bugs, and predacious mites. Using arborist woodchips under your plants will house these beneficial insects as well as improve the soil for your rhododendrons.
- There are also some chemical controls. Any contact insecticide will kill them, but it will also kill everything. If you need to use a chemical control, choose low-toxicity chemicals, such as neem, insecticidal soaps or oils, or pyrethrum. These are broad-spectrum insecticides, however, so apply them with care. Systemics—which are applied to the soil and are taken up through the entire plant, up to the leaves—will also work, but systemics will kill anything that feeds on the leaves, including caterpillars. Some systemics may move into pollen and nectar. It is not recommend to use systemics outdoors.



- ☼ Butterflies are wonderful, but you can't have them without caterpillars.
 - A cultural control that will drive caterpillars away from your favorite plants is the planting of trap plants. Plant something that the caterpillars will like even better than your prized plants and let them use that as their food source.
 - Mechanically, you can pick off caterpillars from target plants that you don't want to see damaged and dispose of them or place them somewhere else.
 - There are no good biological or chemical controls for caterpillars.
 - Philosophically, think about what's going on here: You love the pollinators, and you have to have all life stages of them, so you have to accept a certain amount of damage. There is no reason to have plants killed because of caterpillars, but there are ways of managing them and allowing the larvae to live so that you can have pollinators later.

READING

Chalker-Scott and Bush, *Should We Buy Lady Beetles for Our Gardens?*

Murray, Miles, and Daniels, *Natural Insecticides*.

QUESTIONS

- ☞ Native plants are often touted as superior garden choices because they are adapted to local pests and diseases. Although this may be true, is this resistance of practical value, given our global gardening economy?
- ☞ Pyrethrin is a synthetic form of pyrethrum that tends to be more effective as an insecticide, partially because it persists longer in the landscape than pyrethrum. Why?



Lesson 22

What to Do about Herbivores

This lesson will address some of the worst animal visitors that you'd rather not have in your garden, such as slugs, deer, and rats. The lesson will apply the four prongs of IPM to managing animal pests, but there won't be many biological control options. Thus, the focus will primarily be on cultural and mechanical controls, especially those that modify animal behavior. You will also have to consider the legal implications of managing vertebrate pests. Issues such as humanely dispatching trapped animals are important, as are protection statutes for some native species. This will vary from state to state, so be sure to consult with your state department of wildlife before trapping, injuring, or killing animals.

CONTROL OPTIONS

- ✿ The simplest, most holistic control option is to consider your plant selection. Ultimately, this will not help much if animals are hungry enough.
- ✿ Cultural control is one of the areas where you can manage activity of these animal pests. With some of them, increasing the landscape diversity to support natural predators, especially with smaller animal pests, will be helpful. And you can provide other food sources, such as peanuts or sunflower seeds for squirrels so they don't dig up the bulbs you've planted.
- ✿ Also consider mechanical control, such as fencing, which can keep animal pests out of wherever you don't want them.
- ✿ You can also modify the behavior of animal pests.
 - ⊗ You can scare animal pests with startle inducers, such as scarecrows, motion sensor sprinklers and lights, and flags or aluminum plates that blow in the wind. However, if animals are hungry enough, they will ignore things that would normally scare them and still feed on your landscape.
 - ⊗ Another way to modify behavior is by using deterrents and repellants. Some basic ways that animals can be managed behaviorally include neophobia, which is scaring an animal with something different, such as processed meat (meat and bone meal); conditioned aversion, which involves spraying something on your plant that is harmless to the plant but will upset the animal's stomach; irritation of the mucous membranes in their nose and mouth by using something like capsaicin, the active ingredient in chili peppers; and flavor modification with something like blood meal. Again, if the animal is hungry enough, it will eat anything rather than starve to death.
- ✿ With smaller animal pests, you can consider trapping.
- ✿ There are not many options for biological control of animal pests because there are laws about killing wildlife. But you can have dogs, which can scare away many unwelcome visitors and are one of the best options for keeping larger animals away from your landscape.

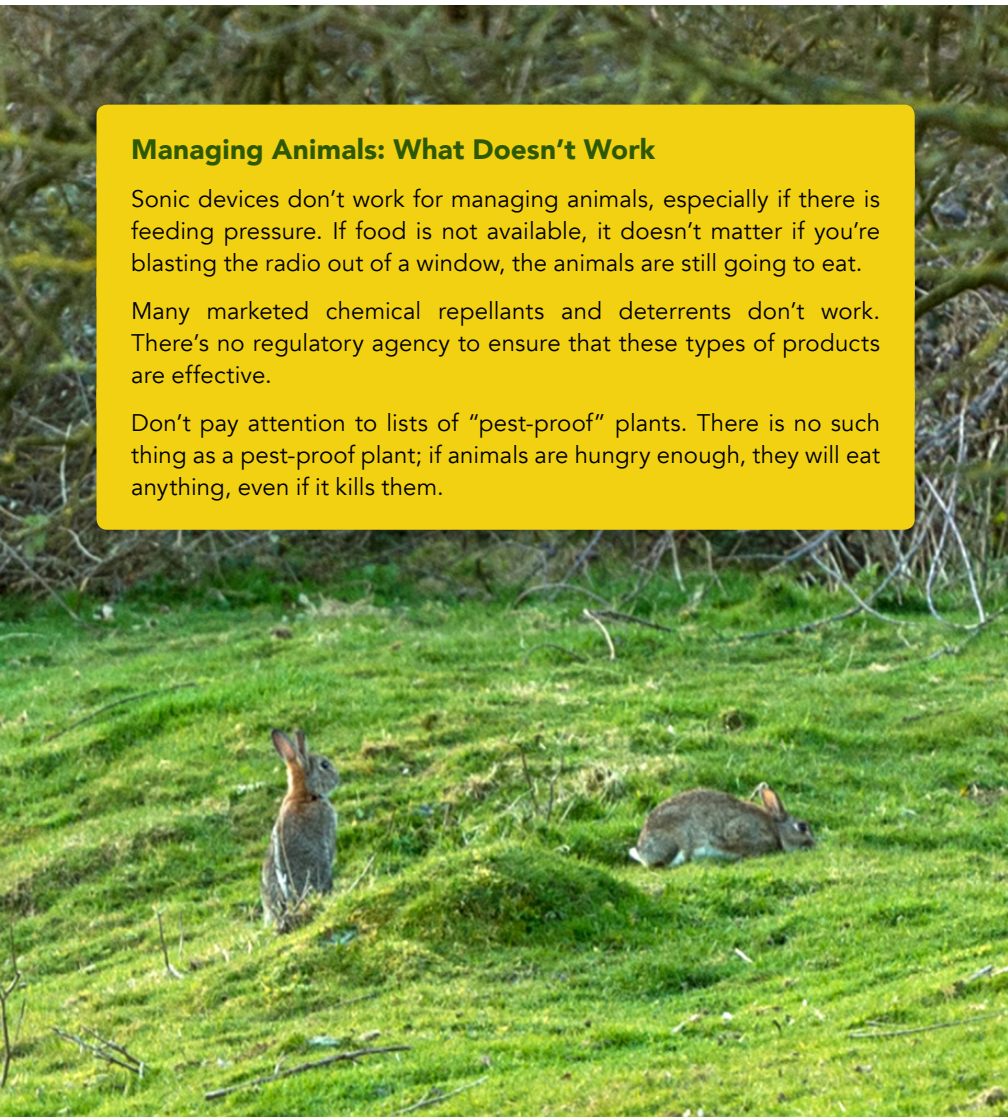
- ❁ When it comes to chemical control, there are few choices. For many mammalian pests, you can't use toxic means.
- ❁ In addition, there are legal issues to consider. Many mammals are legally protected, so you can't hurt them. There are also trap and release laws, which prevent you from trapping an animal on your property and releasing it somewhere else. These laws vary from state to state.

Managing Animals: What Doesn't Work

Sonic devices don't work for managing animals, especially if there is feeding pressure. If food is not available, it doesn't matter if you're blasting the radio out of a window, the animals are still going to eat.

Many marketed chemical repellants and deterrents don't work. There's no regulatory agency to ensure that these types of products are effective.

Don't pay attention to lists of "pest-proof" plants. There is no such thing as a pest-proof plant; if animals are hungry enough, they will eat anything, even if it kills them.



THE WORST HERBIVORES IN THE UNITED STATES

✿ The following is a list of some of the worst herbivore visitors to gardens in the United States.

☼ Slugs can wreak havoc on your plants because they are so large and so voracious. They make huge holes in the ground and can strip plants down to the ground.

- In terms of cultural control, use woodchip mulches and diverse plants as ground cover. Both of these will give habitats to slug predators, such as ground beetles, that will help manage your slug population naturally.
- In terms of mechanical control, you can use an attractant that doesn't do damage to the organism itself to change the behavior of slugs. One of the things that works as a trap and an attractant is beer, which slugs love because of the yeast, water, and sugar that it contains. If you put a bowl of beer out on your landscape, slugs will crawl over the edge of the bowl and eventually drown in the beer. Low-quality beers seem to work best.
- In terms of biological control, many things eat slugs, including predaceous ground beetles, which are voracious eaters of both slugs and slug eggs; slug mites and nematodes, which cause damage by parasitizing and then killing slugs from the inside out; frogs and toads; snakes and lizards; large omnivorous birds; and skunks, foxes, and other small- to mid-sized mammals.
- If you've exhausted all other options, consider chemical control. The only chemical agent that works in controlling slugs is ferric phosphate, or iron phosphate, which you can sprinkle around plants that you don't want damaged by slugs. It will kill the slugs. If you use it, make sure to keep other animals, such as dogs, away from it so that they are not poisoned, too.

Managing Slugs: What Doesn't Work

Broken-up eggshells are one of the things on the internet that are supposed to keep slugs away from your plants, perhaps because they're so sharp. But slugs have a thick mucus covering that pretty much smooths out anything they crawl over.

Copper tape is also said to keep slugs away, but there's no scientific evidence that this would work.



- ⊗ Rats can damage wood by gnawing on it and are generally despised in the landscape.
- There are various cultural control options, including the following: provide habitat for their natural predators, such as birds of prey; store all edible materials in rodent-proof containers, such as metallic or plastic containers (not wooden or cardboard ones); use rodent-proof bird feeders; remove old fruit, seedpods, and nuts from the landscape; secure garbage and food wastes; never leave pet food outside after dark; and dispose of pet droppings in the garbage.
- There are also some mechanical control options, especially if you're trying to keep rats out of your house. You can put barriers below ground to prevent tunneling. You can also reduce hiding and nesting places in your landscape. Simple rat traps that use a spring to trap and kill the rat immediately is the most humane way to kill a rat using a trap. Glue boards are not as humane because the rat is stuck and will most likely starve to death. Multiple-catch traps allow you to catch the rat alive, so you can use the trap again, but the only way to kill the rat if caught like this is to submerge the trap in a tub of water and let the rat drown, which is not very humane. You must euthanize humanely.
- With regard to chemical control, vitamin D₃, or cholecalciferol, is legal and works. It can cause hypercalcemia, which basically turns organs and soft tissues into bone. However, vitamin D₃ also poses a hazard to other animals, such as dogs and cats, which will eat it.

Managing Rats: What Doesn't Work

Corn gluten meal pellets have been marketed as a chemical control for rats. But the active ingredients are corn gluten meal and salt, and the other ingredients are sugar and flour. These "rat biscuits" aren't going to kill anything.

- ⊗ Moles are great for rototilling, or bringing organic matter down into the soil. They are really not a problem except aesthetically. They don't hurt your plants, but they do make molehills and tunnels.
- If you want to control moles from a cultural perspective, remove some or all of your lawn to minimize visual damage. You can replace your lawn with ecoturf, ground covers, and hardscapes. It's easy to tolerate damage from moles if you don't have a pristine monocultural lawn.
 - There are a few ways to use mechanical control. The first is behavior modification, which in this case involves using castor oil repellants, which is the only thing in this category that has any kind of science behind its efficacy. The second is trapping them, but only lethally. This is something that you want to consider: Do you want to kill the moles, or are you willing to tolerate some damage?



- ⊗ Rabbits will leave tooth marks on whatever they bite. There are many online resources that can help you identify damage from rabbits versus squirrels or other types of gnawers.
 - In terms of cultural control, you can increase landscape diversity for predators, which, in this case, would be hawks and other types of predaceous birds. This means having larger trees and shrubs that the birds can use to sit in and look for rabbits.
 - There are also mechanical controls for rabbits. Fencing is probably the best way to deal with rabbits. Use about one-inch mesh chicken wire that is about three feet high. When you're installing it, bend the bottom edge outward slightly and then bury it to prevent them from digging under it.
 - You can change their behavior by removing hiding places, such as brush and briar patches. You can consider using startle devices, such as motion detectors sprinklers, balloons, tape, and aluminum pie pans. In terms of deterrents and repellants, blood meal is ineffective with rabbits. The only way to get rid of them is by trapping them. Find out what the trap and release laws are for your state before you decide to use a trap; you must dispose of the rabbits humanely, if that's even legal where you live.
- ⊗ The large predators of your plants include deer, moose, and elk. These animals can cause a lot of damage by killing and otherwise destroying plants in your landscape.
 - In terms of mechanical control, fencing is probably the best way to keep deer out of your landscape. You can use an electric fence, which is relatively difficult to manage and takes some constant upkeep, or you can use deer fencing, which must be a minimum of eight feet tall because deer can leap. Other types of behavior modifiers include startle devices, such as motion detector sprinklers and lights, which can work if feeding pressure is low enough.

- There are a number of deterrents and repellants, some with good science behind them and others with not great information behind them. Putrescent egg solids have limited effectiveness against deer and elk. They last about three to five weeks, and then even if they're reapplied, the animals get used to the bad smell. Predator urine can be effective. You can also consider dried blood, which will work for a while, but eventually the animals will get used to it and it won't bother them. All of these are most effective when browsing intensity is low.

One thing that is often advertised as a deer repellent is bone meal, which indicates a presence of meat-eating predators, of which herbivores are naturally afraid. But bone meal contains a lot of phosphate, so it should not be used—even though it can work—because it will cause significant damage to your soil chemistry.



READING

Chalker-Scott, ed., *Sustainable Landscapes and Gardens*, ch. 21 (contributor: Pehling).

QUESTIONS

- ✎ Slugs are easily killed with salt, yet this chemical control is not recommended. Why?
- ✎ Beavers, another nuisance species in urban areas, are frequently trapped and removed from areas where flooding damage is significant. Another method is to install “beaver deceivers,” which are devices that allow ponds to be drained but the beavers are not relocated. Which method is likely to be more successful over time?



Lesson 23

Tackling Garden Myths and Misinformation

This lesson will investigate some popular garden products and practices to see if the claims live up to the science. The lesson will offer case studies that fall into some of the categories that gardening information can fall into: practices not based on any consistent, reliable scientific research; misapplied research; overextrapolated research; poorly interpreted research; and poor-quality research. You will also discover the importance of separating correlated observations from causative actions.

Evaluating Garden Information: The CRAP Test

To evaluate garden information, use the CRAP test, which stands for credibility, relevance, accuracy, and purpose.

- How **credible** is your resource (who's the author, and who's the publisher)?
- Is it **relevant** to you as a home gardener?
- Is it **accurate**, or is it very dated?
- What's the **purpose**—to give you good information or to sell a product?

NO CONSISTENT, RELIABLE SUPPORTING SCIENCE

- ✿ Sometimes a garden practice is not based on any consistent, reliable supporting science. Unfortunately, many products and practices fall into this category.
- ✿ An example of this type of garden practice is companion planting. Many popular books talk about the notion that plants either love or hate each other. Most times this is geared toward vegetable gardens.
- ✿ The fact is that plants change their environment. They do this just by living—by changing the soil, by changing the shade, by changing the temperature. Other plants will either do better or worse, depending on what their tolerances are, if they're associated with that other plant. Therefore, this has nothing to do with any kind of sentient feeling; plants do not love or hate anything.
- ✿ One of the older applications of this is the Native American three sisters' approach, which involved planting corn, bean, and squash seeds together. There are scientific reasons behind this. The science wasn't understood as well back when this approach was used, but practice showed that it worked fairly well.

There are often little kernels of truth behind myths.

- Beans are nitrogen fixers, so their presence enriches the soil with nitrogen. Squash acts as a natural, living mulch; it shades the ground and reduces evaporation and compaction. Corn acts as a support for the beans, because beans need to grow on a support. They compete with each other somewhat, but their root systems are different enough so that they don't compete as fiercely as they might if they were more closely related.



Companion planting

- ✿ A second thing that plants can do that makes them look like they are working together in harmony are nurse plants, which are plants that provide something for other plants to use as resources. For example, nurse logs are logs that fall down in the woods and then new trees, shrubs, or mosses grow on the logs. These plants can colonize without competing with all the other forest plants, so they get a resource that other plants don't have. But the plants and logs aren't doing this on purpose; the seeds just fell in the right place and were able to grow.



Nurse plants

- ✿ Another thing plants can do that helps prepare the environment for other plants to come in is phytoremediate the soil. A phytoremediator is a plant that changes something—in this case, it changes soils. Many plants are wetland species, such as willows and poplars, which serve to clean water. They can take up heavy metals and excess nutrients and detoxify pesticides, and in doing this, they make the soil more hospitable to other species that aren't as tolerant of those conditions.
- ✿ Nitrogen fixers—including various legumes, trees, shrubs, and herbaceous plants—add more nitrogen to the soil environment. Even if they aren't sharing the nitrogen with other plants, when they die, that nitrogen becomes available to the soil system.
- ✿ Habitat plants don't directly influence other plants' ability to survive, but they might house beneficial species. For example, if one plant was a great food plant for a pollinating butterfly, the larva would live on the leaves of that plant, and then the butterfly would be able to pollinate another plant. That would benefit the second plant, but it wasn't a direct benefit—it was an indirect benefit.

MISAPPLIED SCIENCE

- ✿ Garden practices can be victims of misapplied science, in which the science is good, but it's being used in a way that is not appropriate. One of the best examples of this are Epsom salts.
- ✿ The Epsom Salt Council have implied that Epsom salt—or magnesium sulfate—helps plants grow greener with higher yields and more blooms, helps seeds germinate, increases chlorophyll production, improves phosphorous and nitrogen uptake, and helps produce vitamins.
- ✿ With many of these claims, the opposite is true if you're growing plants in a solution that is devoid of magnesium. But adding more magnesium is not going to make these things better. So, the claims are based on some science, but the science is not applied well.
- ✿ There is also some scientific evidence behind using magnesium appropriately. Many of these recommendations are better used in agricultural systems than for home gardens and landscapes. For example, magnesium often has to be added to get good fruit production. But there isn't any evidence for using magnesium sulfate, or Epsom salts, in any situation.

OVEREXTRAPOLATION FROM CONTROLLED SITUATION TO FIELD

- ❁ Overextrapolation happens when results from a very controlled situation, such as a laboratory, are expanded to a field situation, where there are so many variables that the situation is nothing like the laboratory.
- ❁ One of the more well-known instances of overextrapolation is black walnut allelopathy. Allelopathy is the ability of a plant—in this case, the black walnut (*Juglans nigra*)—to keep other plants from growing in its space. It's the ultimate competitive mechanism.
- ❁ But this doesn't happen in the landscape. Juglone—the chemical agent in black walnut that is supposedly responsible for powerful allelopathy—can be used in a laboratory to inhibit the germination of lettuce seedlings on pieces of filter paper in Petri dishes.



- ✿ But in fact, no science has shown that juglone in the landscape has any impact on plants growing there, especially other shrubs, small trees, and ground covers. The issue instead is water. If you see areas that have black walnut and nothing's growing under them, it's not because of allelopathy—it's because they're not being irrigated.

POORLY INTERPRETED RESEARCH

- ✿ Researchers are human. Everyone has biases, and sometimes those biases creep into researchers' publications. Peer review helps keep biases from seeping into researchers' work.
- ✿ A paper in *Arboriculture & Urban Forestry*—a journal meant for professionals in the arboriculture field as well as for people who research trees in academia—claimed that mulches were harmful to newly planted trees. There are a number of red flags with this particular article.
 - ⊗ The research did not involve trees—only pots of soil and mulch. This is an overextrapolation: We're going from pots of soil and mulch to trees in a landscape. The containers were filled with soil or media and then were either covered with mulch or not covered—four different types of treatments. Then, water loss from evaporation was measured for three days after watering. This is an odd experiment: It's not using trees, and the pots are only watered for three days. This is not realistic for a landscape.
 - ⊗ The results were all reported, but they were selectively highlighted in the abstract. In other words, the results that most matched the author's bias were the ones that were highlighted. Unfortunately, most people get their information from the abstract.
 - ⊗ Here are the results: On day one, there was more evaporation on the mulched media versus the nonmulched media. On day three, the last day of the experiment, there were no differences between the mulched and nonmulched media. However, the unmulched soil lost a total of three liters of water, and the mulched soil lost a total of two liters, so the mulched soil was much more efficient in retaining water than the unmulched soil. This is opposite of what was proposed in the abstract.

- ✿ This has not been lost on researchers, a number of whom were very bothered by this paper, which was published in a fine journal that has a huge influence over people who practice arboriculture.
- ✿ This is a single paper, and its conclusions are at odds with the bulk of the scientific literature. This means that the paper in question has to clear a very high bar, and other people have to be able to repeat it and confirm the results. But this paper was not confirmed anywhere else.
- ✿ The reason this paper got people so worked up is because the author is well known in the field, so the peer review was probably not unbiased.

POOR-QUALITY RESEARCH

- ✿ With poor-quality research, the information is not good for a number of reasons. A particular paper on bee death and neonicotinoids, published in the *Bulletin of Insectology*, claimed that neonicotinoids are the sole cause of colony collapse disorder. There are several red flags with this paper.
 - ✿ The lead author has a Ph.D. in public health, not in entomology or any related biological field. The other two authors are not scientists.
 - ✿ The English is poor throughout the article.
 - ✿ The journal is not a top-tier journal.
 - ✿ The lead author has a history of doing research that makes spurious claims about the relationship between colony collapse disorder and a specific group of pesticides.
 - ✿ His methodology is flawed.
 - ✿ The interpretation of the results is flawed, including statistical analyses.
 - ✿ He conflates hive abandonment with colony collapse disorder.
 - ✿ He exposed his test bees to unrealistic levels of the pesticide.
 - ✿ He doesn't cite high-profile papers on the topic, which undermines his hypothesis.

CORRELATION VERSUS CAUSATION

- ✿ When you're reading any information, you must keep correlation separate from causation. If two variables are correlated with each other, over time they change in the same way. You can look at this a few different ways:
 - ✿ A causes B.
 - ✿ B causes A.
 - ✿ A and B result from a common cause but don't cause each other.
 - ✿ A and B are not related to one another; their concurrence is coincidental.

Tyler Vigen's Spurious Correlations website (<http://www.tylervigen.com/spurious-correlations>) lists correlations of all kinds of things. For example, per capita cheese consumption correlates with the number of people who died by becoming tangled in their bedsheets.



- ✿ A correlation between two variables does not mean that one causes the other.
- ✿ Controlled studies can determine causation, but they are not always feasible.
- ✿ Correlations can be valuable, but only if they are examined rigorously and other possible causes of the observed phenomenon are eliminated. And then, if you have logically come to this is the only conclusion, even if you can't test it scientifically, at least you've done your due diligence to get rid of other possible causes.

READING

Chalker-Scott and Daniels, *Scientific Literacy for the Citizen Scientist*.

QUESTIONS

- ✎ Look through your collection of gardening books or favorite internet sites. Do some online research to determine the credentials of the authors of some of these. How many of your favorite resources meet the standard of scientific credibility?
- ✎ There is some talk of changing the double-blind peer-review system so that peer reviewers' identities are made public after publication. Is this a good idea?



Lesson 24

Applied Garden Science: Success Stories

This final lesson focuses on two landscape success stories: One is from an ecological restoration effort on a wetland site, while the other is an 18-year home landscape transformation in Seattle. Throughout a landscape transformation, there is a lot of trial and error. For sustainable gardening, keep in mind that it's not only important to figure out what doesn't work, but to understand why it doesn't work based on your knowledge of plant and soil science.

HERONS GLEN WETLAND BUFFER ENHANCEMENT

- ✿ The Herons Glen wetland buffer enhancement was part of a conservation effort to preserve a Garry oak prairie site with two creeks running through it. The creeks are bounded by wetlands, which needed protection with an enhanced buffer of approximately three acres. The site was heavily infested with Scotch broom (*Cytisus scoparius*) and Himalayan blackberry (*Rubus armeniacus*) after decades of livestock grazing.
- ✿ In the first year of restoration, all the invasive plants, including Himalayan blackberry and Scotch broom, were removed by mowing them to the ground. Then, the entire site was mulched with a foot of arborist woodchips. Then, native tree species—such as alder, oak, ash, poplar, and willow—were planted in the soil (not the mulch). Finally, monitoring photos were taken.
- ✿ In the second year, a secondary planting of subcanopy trees was planned, but it was not necessary because nature did the work instead: Squirrels planted acorns from Garry oaks and buried cones from Douglas firs. Other native plants emerged, such as elderberry, snowberry, wild rose, and many annuals and herbaceous perennials. No Scotch broom returned through the mulch layer. The few canes of Himalayan blackberry that poked through were easily pulled, or cut to the ground and painted with glyphosate. At the end of the year, monitoring photos were taken.
- ✿ In the third and fourth years, the canopy of the initially planted trees was rapidly covering and shading most of the site. The shade reduced the ability of noxious weeds (Himalayan blackberry and Scotch broom) to appear. The weeds were replaced by creeping buttercup, which was a native ground cover for the landscape. In drier areas, the trees that had been planted died, but native grasses provided enough shade to keep the invasive plants out. Once again, monitoring photos were taken.
- ✿ In the fifth year, 80 percent canopy coverage and 98 percent tree survival were recorded (counting both planted and volunteer trees). Such an incredible level of success, especially after only five years, was attributed to the use of woodchips.



2002



2003



2004



2006

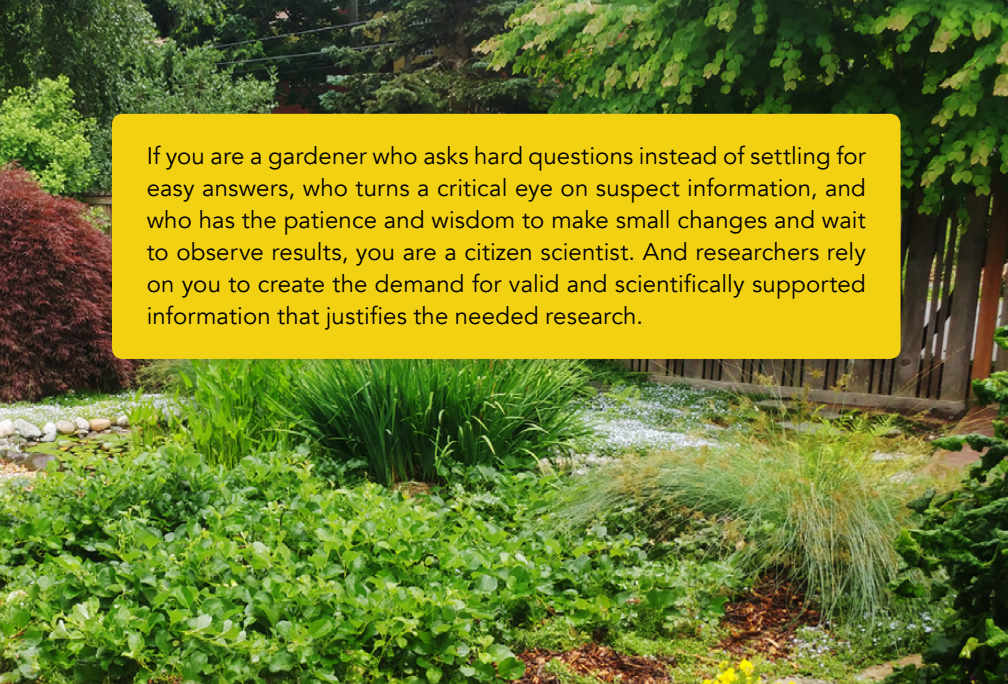
- ✿ The wetland continues to evolve, as landscapes do. Because it became a more inviting environment after restoration, beavers moved in and created dams. The dams created backups and flooded many of the trees. But this is natural succession.

SEATTLE HOME LANDSCAPE

- ✿ The landscape transformation of a Seattle home took 18 years and basically started as a blank slate. Some structure existed, such as an arborvitae hedge, some trees (including a birch tree), some mature rhododendrons, and lots of lawn. Several general approaches were used to transform the landscape:
 - ✿ Arborist woodchips were used to cover, protect, and build soil.
 - ✿ Water was always an issue with the arborvitae hedge; the water bill was reduced by eliminating the lawn, adding hardscape, and mulching.
 - ✿ Continuous maintenance was needed along the neighboring borders of the landscape. Herbicides were used to keep bindweed, bamboo, and creeping buttercup out of the landscape.
 - ✿ Hardscape features were added to direct social traffic and create destination points.
 - ✿ Retaining walls and rockery was added to prevent soil erosion.
 - ✿ Different types of plants were added for biological diversity and to create vertical structure.
 - ✿ Rain barrels were added for carnivorous plants and other container plants.
 - ✿ Alternative food sources for squirrels were provided to prevent them from digging up bulbs.
 - ✿ No fertilizers were used, and very few pesticides were used.

As with all sciences, gardening science is an ever-changing field of study. There are new mysteries to be discovered and new questions to be asked.





If you are a gardener who asks hard questions instead of settling for easy answers, who turns a critical eye on suspect information, and who has the patience and wisdom to make small changes and wait to observe results, you are a citizen scientist. And researchers rely on you to create the demand for valid and scientifically supported information that justifies the needed research.

READING

Chalker-Scott, *How Plants Work*.

QUESTIONS

- ✎ For the Herons Glen project, it was recommended to kill the blackberry and Scotch broom and then lay down plastic sheeting and cover this with eight inches of soil. Would this have been an effective way of controlling the weeds and establishing new trees and shrubs?
- ✎ Even though there were no blackberries, holly, or English ivy near the property borders of the Seattle home landscape, they grew continually in the landscape. Where were they coming from?

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